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POPULATION FLUCTUATIONS OF THE PINE PROCESSIONARY (*THAUMETOPOEA PITYOCAMPA* SCHIFF.) IN FRANCE FROM 1969 TO 1989

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FDC: 453: 411: 145.7 Thaumetopoea pityocampa Schiff.: (44)

RESUME

Une structure de surveillance de la Processionnaire du Pin a été mise en place en France dès 1969. Trois méthodes de suivi ont été utilisées : des prospections extensives et systématiques pour évaluer les niveaux d'infestation, les relevés d'un réseau de placettes permanentes et la capture de papillons mâles par piégeage lumineux. Quatre gradations successives ont été enregistrées (1970-75, 1976-81, 1982-87, 1988-?), soit une périodicité globale de 6 années. Chacune présente des caractéristiques propres : en particulier amplitude et durée de la phase de rétrogradation, qui peut être prolongée dans le cas d'enclenchement de diapause renforcée. Par ailleurs, des décalages existent entre régions, dont le caractère répétitif suggère des cycles épidémiologiques. Les aires successives occupées par la Processionnaire pendant 20 ans permettent de déterminer son aire de distribution actuelle. Enfin, la constitution d'une base de données informatique a été entreprise en 1989 à partir des informations déjà collectées. D'après les premiers résultats, les seules données du réseau de placettes permanentes pourraient suffire à caractériser les gradations. L'objectif à terme est l'élaboration d'un modèle de prévision des infestations de la Processionnaire.

Mots clés : Processionnaire, réseau de surveillance, gradation.

INTRODUCTION

The Pine Processionary is a major defoliator of circum-mediterranean resinous stands. During periods of pullulation, all the pinewoods of the South of France are subject to grave damage. In such cases, broad interventions are often warranted.

Before 1970, the absence of insecticide preparations which could be used without risk to the forest environment and the variations of the annual cycle resulting from bioecological adaptations of the pest to the climate, explain why treatments were so sporadically implemented at the time. From 1970, a new situation arised from the commercialisation of a treatment based on *Bacillus thuringiensis* Berl. and from the publication of the works of Demolin (1969, 1970) and Huchon *et* Demolin (1970), which were directly applicable to the practical realm. New perspectives were opened : it was now possible to envisage a strategy of preventive microbiological interventions.

For that reason, the CEMAGREF set up as early as 1969 a monitoring structure over the whole range of the Pine Processionary in France (CERAFER, 1969; CEMAGREF-INRA, 1980). The objectives of this network were to estimate the risk of infestation of the defoliator and to examine for each particular region the advisability and the optimal dates of treatment. With the data now at our disposal, we are able to present a first analysis of the population fluctuations in space and in time over the last 20 development cycles and to define more precisely the current area of distribution of the Pine Processionary in France.

METHODS OF MONITORING

Systematic and Extensive Prospectings for Infestations

Systematic and extensive prospectings were made by the CEMAGREF within the pest range by counting winter nests, estimating the damages according to a three-level scale and transferring the results to a 1:200,000 scale map :

- mild attacks : some nests present, defoliation absent,
- medium attacks : local concentrations of nests with visible defoliation,
- serious attacks : high density of nests over wide areas with often complete defoliation.

Each year, 10,000 to 15,000 kilometers were covered from October to June of the next year, following comparable itineraries of prospecting. From the vast mass of cartographic data collected from 1969 to 1989, several thousands of points, it was possible to visualize the evolution of insect populations.

Estimation of Infestation Levels in Permanent Plots

Each year, at the end of winter, the standard checking forms completed by the correspondents of the national network were centralized by the CEMAGREF :

- from 1969 to 1980, about a hundred plots distributed in the key sectors of the Processionary area were monitored,
- from 1981 to 1989, the observations made by 350 correspondents concerned with 650 to 750 plots distributed throughout the South of France. Indeed, from 1980 onwards, the working procedure of the network was lightened to increase the number of observation plots. The counting of winter nests on a given number of pines was the only datum taken into account. The objective in view was to build up of a database lending itself to statistical analyses.

Trapping of male Adults of Processionary

Male adults of Processionary were catched with 24 Demolin's model light-traps, distributed among the main zones of the defoliator range.

Table 1 : Gradation sequences of the Pine Processionary in France from 1970 to 1989
Temporal sequences of the different phases of the 4 gradations recorded (1970-75 : 1976-81 : 1982-87 : 1988-?) for the large geographical regions of the Processionary range.

1 - Progradation
•2 - Culmination, pullulation
3 - Retrogradation, recession
4 - Pessimum, latency
► Small population increases after diapause

NW = Brittany
W = Atlantic coast : Loire, Gironde
SW = Aquitaine
S = Languedoc, Roussillon, South of the Massif Central
SE = Provence, Riviera
E-NE = Rhône and Saône valleys
N = Loire valley

cycle	NW Bretagne	W Côte atlant. Loire-Gironde	SW Aquitaine	S Languedoc Roussillon Sud M.Central	SE Provence Côte d'Azur	E-N.E Vallées du Rhône et de la Saône	N Vallée de la Loire
1969-70	•2	•2	•2	1	1	1	1
1970-71	•2	•2	•2	•2	•2	•2	•2
1971-72	•2	3	3	•2	•2	•2	•2
1972-73	3	4	4	3	3	3	3
►1973-74	3	4	4	3	4	4	4
1974-75	4	4	4	4	4	4	4
1975-76	1	1	1	1	1	1	1
1976-77	•2	•2	•2	•2	•2	•2	1-2*
1977-78	3	3	•2	•2	•2	3	•2
1978-79	3	3	3	3	•2	3	3
►1979-80	2	3	3	3	3	2-3	3
1980-81	4	4	4	4	4	4	4
1981-82	4	4	4	1	•2	1	1
1982-83	1	1	•2	•2	•2	•2	•2
1983-84	•2	•2	3	•2	•2	•2-3	•2-3
1984-85	•2	3	3	3	3	3	•2-3
1985-86	3	4	4	4	4	4	4
1986-87	4	4	1	4	1	4	4
1987-88	4	4	•2	1-2*	•2	1	4
1988-89	1(?)	1(?)	•2	•2	•2	1-2*	1(?)

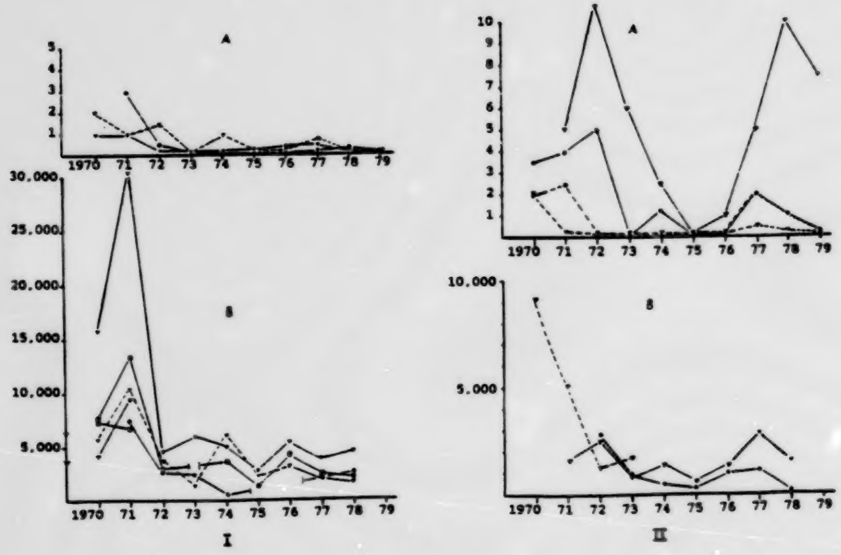


Figure 1 : Fluctuations of Pine Processionary populations recorded in some permanent plots of the monitoring network from 1970 to 1979
(A) Average number of winter nests per pine and (B) Number of males catched in the light-traps
Permanent plots of I) the Atlantic coast of Aquitaine (SW) and II) the coastal Brittany (NW)

RESULTS AND DISCUSSION

Gradations of the Pine Processionary Populations in France from 1969 to 1989

1) Fluctuations in time

Table I presents for the various geographical regions involved, the sequence of the different phases of the gradations recorded over 20 years. Four successive gradations were underscored, the last one now being in progress : 1970-75, 1976-81, 1982-87, 1988-95(?), thus corresponding to a global periodicity of 6 years per cycle. Generally, the culminations last 2 years (cycles 1970-71 and 1971-72, 1976-77 and 1977-78, 1982-83 and 1983-84, 1987-88 and 1988-89) and the progradation phases only 1. On the other hand, the retrogradation is more variable : abrupt in 1972-73, it persisted after the pullulation of 1976-77. Maps figure 2 are given as examples of the extreme differences between the states of culmination and of latency. These extensive data are corroborated by the infestation sequences of the network of permanent plots and by the results of light trapping. For example, for the 1969-79 period, we find again figure 1 the culmination phases of 1971-72 and of 1977-78.

In spite of this general periodicity, each gradation has its own characteristics. For instance, the powerful pullulations of 1970-71 and 1977-78 contrast with the one of 1984-85, of low magnitude. The population collapse seems all the more abrupt as the culmination was high (over-population). It is what we note in 1973 throughout the range of the Processionary. On the other hand, after 1978, three to five years were necessary to achieve a general latency. This could be explained by the very unfavourable conditions of 1977, which provoked the setting up of prolonged diapause (Demolin, 1974) affecting a large part of the population. The emergence of adults so deferred for two or three years prolonged the retrogradation. A comparable phenomenon resulting from alimentary stresses due to over-population would be at the origine of the population increases clearly noted in 1974 and 1980 (table I).

These arrests of development thus disturb the progress of the gradations. Nevertheless, as for the larch budmoth *Zeiraphera diniana* Guenée, regular cyclic pest of the alpine arc, the quantitative reduction and qualitative alteration of the foliage after culmination would play a prominent part in the self-regulation of the Processionary (negative feed-back : Benz, 1974; Battisti, 1988).

2) Fluctuations in space

Correlatively with the sequence of gradations, the Processionary goes through a succession of maximal territorial expansions when culminating and of withdrawals when in latency periods, during which only subsist some infestation spots. In other respects, there are time-lags of attacks between regions, whose repetitive character suggests epidemiological cycles.

Thus in the western part of the area, the four observed gradations originated in the Atlantic coastal stands of the

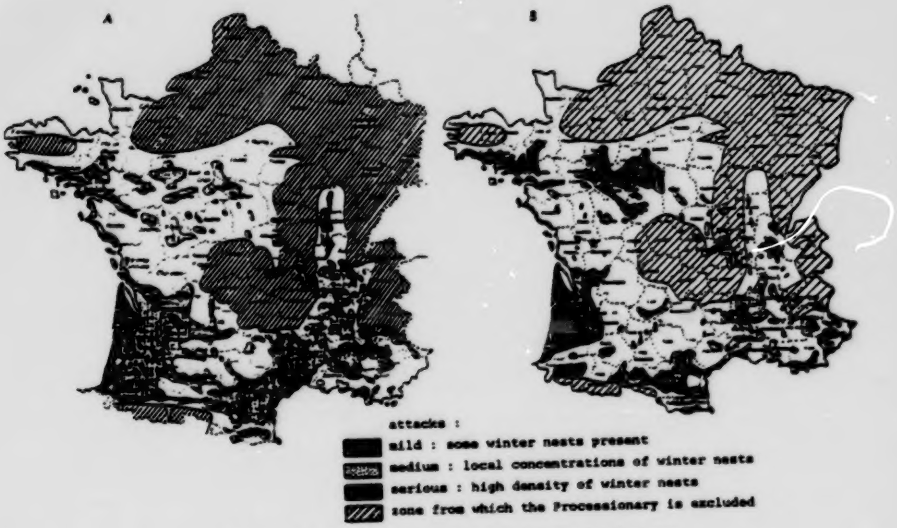
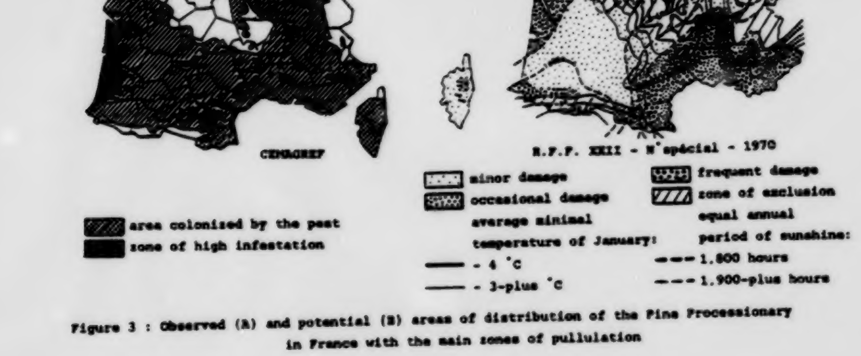

A
B
attacks :
mild : some winter nests present
medium : local concentrations of winter nests
serious : high density of winter nests
zone from which the Processionary is excluded

Figure 2 : Examples of Pine Processionary infestations
Biological cycle of (A) 1976-77 (culmination phase) and (B) 1985-86 (latency phase)


A
B
area colonized by the pest
zone of high infestation
minor damage
occasional damage
average minimal
temperature of January:
- 4 °C
- 3-plus °C
frequent damage
zone of exclusion
equal annual
period of sunshine:
1.800 hours
1.900-plus hours

CEMAGREF

R.F.F. XXII - N°spécial - 1970

Figure 3 : Observed (A) and potential (B) areas of distribution of the Pine Processionary in France with the main zones of pullulation

Aquitaine and then spread over the inland Aquitaine and the North (Brittany and Loire valley).

In the eastern part of the area, this behaviour is less clear but the most frequent starting sectors are localized in the coastal pine forests of the Rhône mouth and of the Var, as also in those of the north-western part of the maritime Alps. The attacks then become widespread in the Lower Rhône valley, to subsequently spread towards the North.

Area of Distribution of the Pine Processionary in France

Demolin's works (1969, 1970) allowed to define from the study of the ecoclimatic requirements, a potential area of distribution of the Pine Processionary in France. By comparison with this theoretic range, the compilation of the informations collected over 20 years on the regions actually colonized by the insect permit to note (maps figure 3) :

- a good general coincidence on the northern boundary and on the periphery of the Massif Central (limiting factors corresponding to a reduced period of sunshine and high thermic minima during winter),
- a permanent presence, not suspected at the outset, of the Processionary in the Upper Loire and Allier valleys , owing to favourable southern and eastern aspects,
- pullulation zones which were previously under-estimated in the Atlantic sector (Brittany and Aquitaine), the mid-valley of the Loire, the south-western part of the Massif Central and the northern boundary of the Pyrenees.

Perspectives of Use for the Network

The approach methods used from 1969 allowed to follow the last four gradations of the Processionary and to define precisely its range in France. These elements form a solid basis for elaborating a forecast model for the infestations. The building up of a computer database for statistical analyses, such as it was undertaken in 1989, falls short of this objective. Constituted by a set of files (plot file, infestation and climatic files per year), it already allowed us, from the sole data of permanent plots, to characterize for example the sudden recession observed between 1985 and 1986, and the progradation of 1987. In the following table, the infestation classes for plots correspond to the percentage of attacked trees: 1=[0,10%[2=[10,25%[3=[25,60%[4=[60,100%].

recession

1985-1986

		1	2	3	4	Tot.
1984-85	1	65.9	2.5	1.3	0.0	69.7
	2	11.7	2.5	0.7	0.0	14.9
	3	5.8	2.5	1.3	0.3	9.9
	4	3.3	0.5	0.8	1.0	5.6
	Tot.	86.7	8.0	4.1	1.3	100.1

progradation

1986-1987

		1	2	3	4	Tot.
1985-86	1	80.0	4.6	2.0	1.0	87.6
	2	2.8	3.3	1.2	0.5	7.8
	3	1.0	1.0	0.8	0.7	3.5
	4	0.2	0.0	0.3	0.7	1.2
	Tot.	84.0	8.9	4.3	2.9	100.1

CONCLUSION

The annual surveys of the network of permanent plots, with standardization of collected informations and computer processing of data, supply first results consistent with the methods used to date. This monitoring technic of the Pine Processionary population levels reveals itself to be very promising. Then, it is worth being systematized and gone deeper into, which will be done in collaboration with the CEMAGREF by the recently founded "Département de la Santé des forêts". The objective is to forecast and anticipate the Pine Processionary infestations, to be able to work out suitable intervention strategies. Therefore, this network could constitute a research tool and result at term in prognosis methods, thanks to the elaboration of prediction models.

ACKNOWLEDGMENTS

We are gratful to B. Juvy for his technical collaboration. We also wish to thank all the foresters who participated in this monitoring network.

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ALLELOPATHIC POTENTIAL OF EUCALYPTS IN INDIA

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FDC: 181.41: 176.1 Eucalyptus spp.: 176.1 Lens esculentum L.: (540)

SUMMARY

Eucalyptus has been accused to discourage growth of annuals in its vicinity.Allelopathic property of the tree has been evidenced,as the reason of this negative tree-herb interaction. Allelochemics in their glycosidic form leach out and act as such. Polar and the non-polar chemicals of the leaves have been identified as the active principles. The volatile oil vapour component of the leaves being heavier than air adds to the allelopathic property of the tree. These vapours, it has been evidenced, act upon by adsorption on the soil particles as well as through direct aerial contact. The impact of allelochemics ranges from retardation to complete inhibition of germination,seed vigour, seedling growth,apart from decrease in the content of water, and above all the economic yield. The plantation also adversly, affects the performance of the Lens esculentum crop grown in the adjoining field.

Keywords: Allelopathy, eucalypt, Lens esculentum, allelochemics.

INTRODUCTION

Eucalyptus in India, has assumed prominent place through various afforestation programmes during the last two dacades. For economic reasons, it has been adopted as a monoculture crop on any available land with disregard to the ecological factors. Decreased bio-diversity in the area of eucalypt forest (Bhaskar and Dasappa, 1986) and economic loss to agricultural crops have countered the claims of benefits by its promoters. Looking at the gravity of controversy,the Ministry of Environment and Forests, Government of India, trusted us the work of finding reasons in this direction.

Though all the factors required for normal growth of annuals on eucalypt floor are adequate, still it lacks vegetation. Allelopathy (interplant action in which a plant releases certain chemicals which through environment affects the growth of neighbouring species) has been proposed (Kohli, 1987; Kohli et al., 1987) to be the reason of anti-phytosocial property of the tree.

In order to acertain the role of allelopathy, experiments in the lab and the field were conducted on *Eucalyptus tereticornis* Sm.,*E.globulus* Labill. and *E.citriodora* Hook. maintaining nearly 30 species as the target plant types. However, in this presentation a part of the work on allelopathic impact of only *E. tereticornis* on *Lens esculentum* L. alone has been reported.

EXPERIMENTAL METHODS

Bioefficacy Of Isolated Allelochemics

Allelochemics were isolated from fresh and shade dried leaves of *E. tereticornis* (8 yr old plantation) as per procedure of Kohli *et al.* (1985). *Volatile oil* was extracted through hydro-distillation and subjected to column chromatography over almino Gr.1. Cineole and limonene were eluted successively with hexane and benzene. Elutions were characterized by CO-GLC and IR spectroscopy. Pure line uniform seeds of *Lens esculentum* L. var. AL-76 with 100 per cent viability were used for the bioefficacy study. Maintaining 400 seeds (in four replications) per treatment, the germination trials following International Seed Testing Association (ISTA, 1976) rules, were conducted in environment controlled dual chambers. The total water content was measured by the method of Dean and Stark (1980). Pilot experiments were conducted to decide the concentration.

The effect of the vapours of Eucalyptus oil and components was assessed through - a) continuous aerial column, b) adsorption of vapours on the soil particles and c) simultaneous vapour column and adsorption on the soil. For a) above, continuous column of vapours was maintained from the requisite concentrations of respective oils in environment controlled fumatorium chambers. The propagules were subjected to bioefficacy trials in the chambers. For the b) above, the soil (Sand :Clay:: 4:1, w/w) was exposed for 24 hr (with intermitant mixing) to the vapours generated by demothing vapourizer under air displacement pressure of 126.2 $m^3 . h^{-1}$ from requisite concentration of respective oils in the fumatorium. It is this oil adsorbed soil which was used to study the bioefficacy. For the third condition, i.e. c) above, the conditions of a) and b) above were applied simultaneously. The experimentation was carried as per the ISTA (1976) rules.

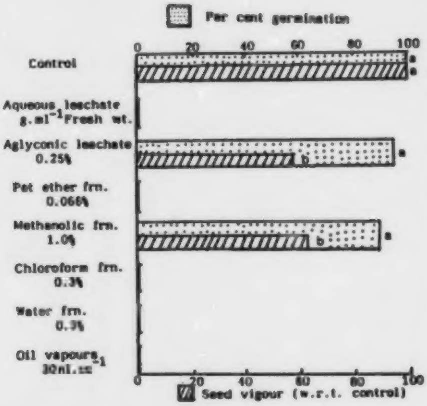
Field Trials

E. tereticornis plantations (over 8 yr old, 80±15 cm girth and 2x2 m intertree distance) located 35±5 km on west, north and south of Chandigarh (30°.7'N, 76°.8'E, 260 msl) were selected. Uniform beds were prepared at 3 sites in each location on the floor under the eucalypt plantation. Similar beds at nearly 50 m away on the east, south and west of the plantation, to serve as control, were also prepared. Viable 400 seeds of *L. esculentum* were sown in each bed as per conventional agricultural practices. Observations on different parameters were carried at regular intervals. In order to assess the contribution of volatile oil component of the tree, beds under the canopy were also prepared by replacing the top 2 ft deep soil with the soil from control after lining the dug area with polythene sheet to check the transfer of allelochemics, if any, from adjoining soil or the eucalypt roots. Experiments were also conducted to assess the influence of plantations on the Lens crop in the adjoining south facing fields. At the time of harvest, observations on various parameters were made at different distances from eucalypt tree line. To compare the degree of impact on different parameters of growth, the values obtained at particular distance from the Eucalyptus line were normalized with maximum value of the respective parameter. The total decrease in the performance of the parameters, up to a distance was assessed using formula: $s(d-24)/2)$ where s: degree of slope,d: distance from plantation.

RESULTS AND DISCUSSION

Bioefficacy Of Isolated Allelochemics

It is evident (Figure 1) that the aqueous leachates,pet. ether,chloroform or water fractions from Eucalyptus leaves inhibit germination of L. esculentum seeds. In contrast, the aglyconic leachates or the methanolic extract fraction did not affect the per cent germination at all. In case of treatment with aglyconic leachates or methanolic extract frn., though the germination was not affected, the speed of germination to some extent and the growth of seedlings, to a great extent, was adversly affected. The content of water in the samples was also low.

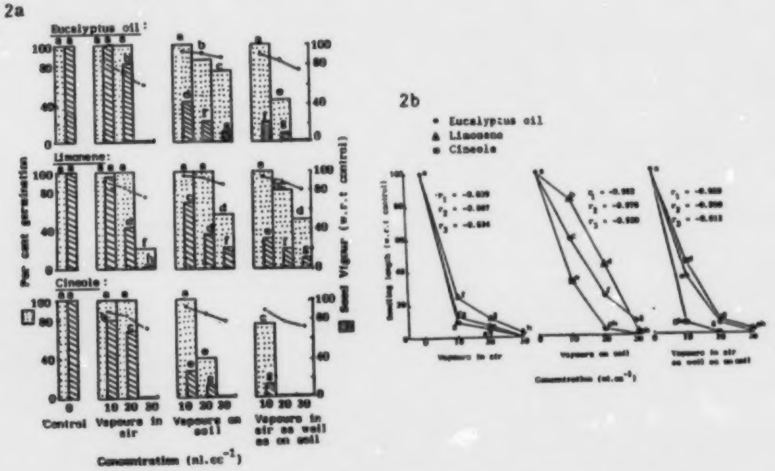


Seedling length (cm) w.r.t. control		% water content w.r.t control
Radicle	Plumule	
100^{a}	100^{a}	100^{a}
-	-	48.67^{d}
12.81^{b}	12.40^{c}	75.31^{b}
-	-	66.98^{c}
10.84^{b}	17.31^{b}	75.66^{b}
-	-	67.35^{c}
-	-	66.53^{c}
-	-	62.35^{c}

Figure 1: Effect of different fractions from E. tereticornis leaves on various germination parameters of L. esculentum. (same superscript symbols represent insignificant difference employing Duncan's multiple range test)

In nature, a plant can release allelochemics through leachation in water (aided by agencies like rain,dew, mist or fog) or upon decomposition of litter or exudation from roots or volatilisation from aerial parts (Rice, 1984). It is generally believed that the secondary metabolities for their transport within the plant or for release into the environment occur as glycosides, to be in their water soluble form (Goss, 1973). Their release maintains the balance in the system beside retarding the growth of the other plants. The positive and the negative Fehling solution test of aqueous and aglyconic leachates, respectively, support this. The bioefficacy data confirms the fact that aqueous leachates contain allelochemics which are active as glycosides.

The inhibition of seed germination and retardation of other parameters by fractions extracted in pet.ether shows that the allelochemics are possibly non polar in nature. In addition, the inhibitory response exhibited by chloroform or water fractions (derived through polar solvent) or methanolic fraction from the residue left undissolved in pet. ether emphatically suggests that some of the allelochemics are polar in nature. In other words, E. tereticornis contains polar as well as nonpolar allelochemics that get released in the soil upon decomposition of litter. It may be added that those seeds which do not germinate in response to any of the given treatments were found to be viable. It shows that the allelochemics cause inhibition of physiological functions and are not fatal in action. However, this effect pertains to only a short period of contact. What happens to seeds that receive prolonged treatment has not been acertained. It is likely that the fallen leaves upon decomposition keep on adding the forces responsible for checking the germination of seeds. Mechanism of checking the germination, is out of scope of this paper. However, we have evidenced that it is accomplished by arrest of embryonal respiration.


2a

2b

Figure (2a and b): Effect of Eucalyptus oil, limonene and cineole through continuous vapour column, or adsorbed on soil or through combination of both, (2a): on germination percentage, seed vigour and water content of seed/seedling; (2b): on seedling length of L.esculentum. Same superscript symbols repesent insignificant difference employing DMRT and, 'r' represents the correlation coefficient between concentration and mean seedling length in response to Eucalyptus oil (r_1), limonene (r_2) and cineole (r_3).

All the three oil vapours (Figure 2 a, b) under any set of conditions tried ,show a dose response typical of a chemical based action. The retardation in different parameters was more in response to oil vapours adsorbed on the surface of soil to those of continuous vapours. Nevertheless, under the combination of both the situations, the retardation leading to inhibition was still more. In nature, the oil vapours form a continuous flow from the leaves to the soil because of being heavier than air. These remain adsorbed on the soil till they flow down with runaway or gravitational water. So, the situation studied in combination of the two sets appears close to the one prevalent in nature. Among the components of soil, pure cineole rather than limonene tends to be more phytotoxic. The retardatory impact on the growth of seedlings in response to the oil vapours adsorbed or/and available in the air is evident (Figure 2b). However, unlike in case of germination, here the impact was more through vapour column in the air, compared to that adsorbed on the soil. Under simultaneous conditions, nevertheless, the effect was more. The negative values of correlation coefficients close to 1.0 demonstrate a strong reciprocal relation between the seedling growth and the oil vapours applied.

Field Trials

There is hardly any difference (Table 1) in the germination attributes of the seeds sown under or away from eucalypt plantation. However, the impact on the growth and yield of the plant was tremendous. The average height and biomass of the whole plant (including primary root) compared to control was drastically diminished in those grown on eucalypt floor with the same or the soil replaced from control. The impact was relatively more in the former case. This evidences that apart from the oil vapours that cover the air of undercanopy area, the phytotoxins arrested in the soil of the plantation also contribute to the negative effect. The effect on water content though statistically significant, was marginal. It is noteworthy that in contrast to 279 g. m^{-2} seed yield obtained from control crop, those grown under eucalypt did not even flower for another 30 days.

Table 1 : Performance of L. esculentum plants grown under canopy of eucalypts with soil from control or the original soil of the plantation, and on the soil away from E. tereticornis plantation.*

Treatment	% germination w.r.t. control	% Height (cm) w.r.t. control	% Biomass w.r.t. control		% Water content w.r.t. control	Yield (gm.m^{-2})
			35 days	70 days		
Control	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}	279^{**}
Eucalypt floor						
-soil from control	94.87^{a}	71.11^{b}	34.42^{b}	50.64^{b}	95.12^{b}	-
-with same soil	97.44^{a}	18.03^{c}	54.29^{c}	13.31^{c}	89.59^{c}	-

* Same superscript symbols on mean vaoue of respective parameter represent insignificant difference employing DMRT (Duncan, 1955). ** 1.55 g. $plant^{-1}$.

It is obvious (Figure 3a) that as the distance from the *Eucalyptus* tree line on south ward increases, the average cumulative length of primary root and shoot per plant, and cumulative biomass of root and shoot per unit area increses almost constantly upto 9 m. The plant density and the pulse yield per unit area shows a regular increase upto 12 and 11m distance from eucalypt tree, respectively. Beyond 12 m or upto 20 m all the parameters understudy showed stability. It is worthy to note that correlation coefficient of almost all the parameters with respect to distance from the tree line is close to +0.95. Such a strong positive correlation signifies direct relation between growth performance (including economic yield) and the distance from the tree.

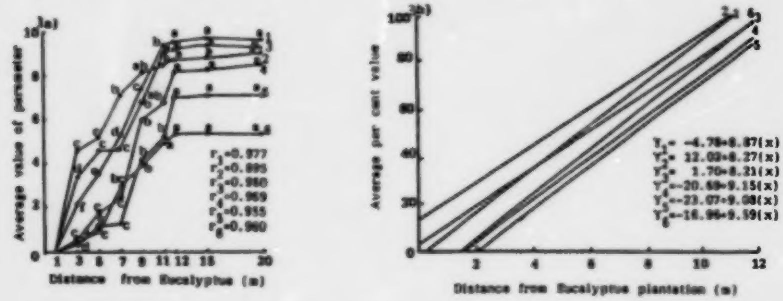


Figure 3: (3a):Mean values of different parameters; (3b):the regression values of normalised mean values of different parameters (1: crop density, 2: average root length,3: average shoot length,4: root biomass,5: shoot biomass, 6: pulse yield) w.r.t. distance of *L.esculentum* from eucalypt plantation. Same superscript of respective curves represent insignificant differences applying DMRT.

The regression equation of the normalized values (Figure 3b) of each parameter, index the inclination of the slope. The degree of slope, in turn, signifies the sensitivity of a parameter to the distance from tree. The values of the performance of any parameter at any given distance from tree could be calculated from the respective regression equation. It is explicit from the equations that the performance of each parameter under study gets drastically affected proportionally because of closeness to the *Eucalyptus* belt. It, therefore,gets implied that greater the distance (upto nearly 11 m),lesser the allelopathic impact of *Eucalyptus* plantation on the crop. Based on the formula, the average per cent decrease of each of the parameters of *L. esculentum* up to 12 m from *Eucalyptus* was calculated from the three locations. It was found that the crop density, root length, shoot length, root biomass, shoot biomass and the yield were reduced by 53.1, 49.6, 49.3, 55, 54.5 and 57 per cent,respectively from that of unsheltered control. It was found that the performance of all the parameters gets reduced by nearly 50 per cent from that of control (unsheltered crop) or distance of 12 m or beyond from eucalypts.The study also gains support from the visual observation and experience of farm owners. Indian farmers holding small land face drastic loss of yield. One has, therefore, either to leave 7 to 8 meter wide belt around their cropped area towards *Eucalyptus* or bear loss in yield and also increase per unit processing charges. On the north facing sites of *Eucalyptus*, additional negative effect on crop is caused due to shade of the tree.

POSSIBLE CONSEQUENCES AND SUGGESTIONS

The large scale monoculture plantation of eucalypts covered under social forestry programme is not only diluting the concept of forest (self sustaining climax system) but also ignoring the demands of the society. No doubt, we are hard pressed for forest products but our concern for deteriorating environment is also great. We have to evolve some strategy to conserve our environment and meet economic demands. The Special Interest Conservation Policy which has been unfortunately at the present adopted by the developing nations and the societies is certainly fraught with failures and dangers because one may manage and conserve one resource at the cost of another. The efforts through this policy will lead to "ecological boomeranges" or "ecological backlash". The detrimental consequences remain unforeseen because of public misconception and the public and private sector support (especially in the present context). The cultivation of eucalypts as a crop cannot take us close to meeting economic demand and conserve environment. Any plantation deed that meets the economic,social and above all ecological needs holds the key to the Total Ecosystem Conservation Policy. Eucalypts or for that matter any other single tree type planted as a crop will lead to backlash.The better policy would,therefore be to encourage mixed culture plantation of mainly indigenous species along with some exotic ones depending upon the edaphic and environmental factors.

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BREEDING AND SEED PRODUCTION OF FOREST TREES IN LATVIA

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FDC: 165.3: 232.311.3: (474.3)

SUMMARY

In the mid 1950s an intensive forest genetics and tree improvement program began in Latvia. By 1960 the first seed orchards were established. By 1975 first generation seeds orchards for 14 tree species covered 965 ha. Scots pine orchards, the major species of Latvia, currently produces from 800 to 2,650 kg of seeds. Several species of larch and hardwoods, such as common oak and European ash, have also produced large quantities of seed, while Norway spruce orchards as old as 25 years have not.

To improve the quality of the seed open pollinated progeny tests of seed orchard material have been conducted for the last 15 to 17 years. On the basis of these field tests selections for second generation orchards are made.

In the near future second generation seed orchards for Scots pine, Norway spruce, European and Japanese larch, European birch, black and grey alder, Douglas-fir, and Murrey pine will be established.

INTRODUCTION

Intensive forestry which can result in increased productivity, improved stand composition and higher stem quality can not be accomplished without improved forest regeneration methods based on the latest achievements of forest genetics and tree breeding.

Seed orchards, resulting from the efforts of the selection and propagation of outstanding individuals, groups of individuals, and isolated forest tree populations, have of late gained in practice. these orchards serve as the basis for improved seed production in quite a number of countries which have developed intensive forestry practices.

SEED ORCHARD ESTABLISHMENT AND MANAGEMENT

It was in mid-1950s that an intensive breeding-oriented analyses of existing stands, selection of plus trees, and large scale scion grafting of diverse tree species was started in Latvia. The first seed orchards were established in 1960. First generation seed orchards for 14 tree species (local and introduced) had been established by 1975 covering a total area of 965 ha. Abundant yields of Scots pine seeds, as well as those for a number of larch species and also hardwoods, were obtained on a regular basis. The seed orchard crops for Scots pine, the principal tree species of Latvia, amounts annually from 800 to 2,650 kg of seed which meets the needs of Latvia. First generation seed orchards at 10 to 15 years of age start to yield seed in appreciable quantities necessary for large-scale production of planting stock, while bumper crops have on occasion amojnted to 15 kg of seed per ha.

It should be pointed out that the pine of Latvia or the so-called Riga pine, once exported to a number of European countries, has for centuries been in high repute for slim taper of its stem, high increment figures and tiop-quality timber. International trials of Riga pine in geographically different localities started in 1908 and 1909 and again in 1937 and after World War II only corroborated the stability of its features. That is why even today Riga pine seed obtained from seed orchards are exported on regular basis.

In regards to the other species of common use, Norway spruce, no appreciable seed orchard yields of cone have been encountered (the oldest orchards are from 20 to 25 years old).

The annual seed orchard crops in Latvia between 1984 and 1988 have been: for Scots pine - up to 2,650 kg, for a number of larch species - up to 240 kg, for common oak - up to 161 kg, for European ash - up to 111 kg and for other species - up to 530 kg. There have been practically no seed crops for spruce in natural stands as well.

When using seeds it is to be noted special care was taken in observing the principles of crop zonation. Seeds of diverse (e.g., high-resistance) clones are to be collected and used within the district of origin.

In the course of growth and continuous exploitation of seed orchards the problem of establishing those of the next generation inevitably turns up. Advances in the field of forest tree breeding, a need for genetic enhancement as well as ageing of first generation seed orchards serve as the background here.

It was in 1975 that a new program for producing selected forest tree seed, which apart from other aims, was to provide for improvements in clonal composition of stands after a whole set of desirable characteristics was established at the Latvian Research Institute of

Forestry Problems. With this end in view we attempted in the course of developing first generation orchards, to employ clonal progeny trials to identify the hereditability of such characteristics as growth intensity, survival and resistance.

PROGENY TESTING

Seed orchard clone progeny trials against ecologically diverse backgrounds have by now been run for some 15-17 years. Evaluation is made for a number of characteristics which describe forest productivity such as: solid volume, growth rate, stability of increment depending upon age and diverse ecological conditions, resistance to diseases and general survival of trees. Diallel crossing of individual sets of clones to explore the hereditatory behaviour of these characteristics is made. Progeny trials following open pollination have veen established on a regular basis in different years. Different kinds of progeny trials are made. In short-term (from 4 to 6 years) trials a great number of clones are simultaneously tested for resistance to diseases and survival. Such trials are usually established in nursuries and planting is close (0,25 x 0,25 m) and arranged in bands with 8 replications in each.

A pronounced distinction between progeny of different pine clones was observed. For example, for needle-cast disease the distinction was greater with less intensive infection. Clones coming from the North-Eastern part of Latvia are distinguished by high resistance to the above disease.

Long-term (from 15 to 20 years or more) trials are established to follow up the dynamics of tree growth and assess the productivity in terms of volume increment. Such trials are usually conducted against two kinds of ecological background, 4 to 8 replications are employed using from 60 to 120 transplants in each replication. Different progeny families have been observed to exhibit substantial differences at the age of 10 to 15 years.

In addition to the evaluation of graft-established individuals in the first generation seed orchards, another sequence of trials is conducted where the clones are evaluated in terms of phenology, type of sexualization, intensity of flowering, degree of self-polination, amount and quality of seed crop. For pine, a number of clones having poor seed crops as well as those of poor cone dehiscence, have been culled from the orchard.

SECOND GENERATION SEED ORCHARD

Selection of clones for second generation seed orchards is based on both of the above sets of criteria: evaluation of progeny trials and characteristics for graft-established individuals in the first generation seed orchards. The trees of the clones selected are distinguished by high productivity in terms of volume at a definite geographical site and high survival. Female flowering of a normal level with simultaneously ripening of a top-quality seed crop is also required. To achieve optimum conditions for pollination, clones with a pronounced male sexualization are also incorporated into the orchard.

Breeding material of a second generation of selection, in the form of sets of the best clones or hybrids, has, except for Scots pine, been or is being developed for other native or introduced forest tree species such as: larch, Douglas-fir, birch, aspen, and alder. For larch, for example, improved-grade breeding material, consisting of super-productive clones have been selected from first generation seed orchards. These now cover a total area in Latvia of 57.6 ha. These orchards are also used for artificial hybridization of the best clones of larch hybrids including: European x Japanese and Japanese x European larch hybrids.

Hybridization of Douglas-fir has been carried out with the hybrids: var.viridis x var.caesia, and var.caesia x var.viridis. Here, the best combinations of crosses are already represented in a second generation seed orchard in the western seed production zone of Latvia.

During the years to come, seed orchards of Scots pine, Norway spruce, European and Japanese larch, European birch, black and grey alder, Douglas-fir, Murrey pine are to established. Plantations of these in the form of geographical progeny trials already exist in different regions of Latvia and have been followed for 10 to 20 years. Distinguished provenances having excellent survival will be selected for the new orchards.

Now, some data as to the management problems involved with second generation seed orchards. Establishing these orchards in Latvia has been going on since 1986. By 1990 they will cover mainly an area of 160 ha. Second generation seed orchards, unlike the earlier ones, which were set up at every forestry enterprise, will be laid only in the principal forest seed production zones of Latvia - Eastern and Western. Each zone will have a centre of selected seed production, on existing with the Kuldiga Forestry Enterprise for the Western zone and the other - with the Forest Experimental Station "Kalsnava" for the Eastern zone. Second generation seed orchards will be built up around these research centres.

Normal seed-bearing time for these orchards is expected to be for 50 years, with a mazimum yield at the age from 20 to 40 years. Genetic improvement in terms of the forest crop from these plantations to be established is expected to be within the range of 20 percent.

In Latvia, second generation seed orchards are established on improved forest lands prepared by continuous plowing. Planting patterns are regular with planting distance of 5 x 5 m to 7 x 10 m. The whole site as well as individual seedlots are enclircled by wire fencing to keep out wild animals. Facilities for protection against various pests, diseases and fire are provided. Pollen contamination is avoided by strips of tree species other than those in the orchard.

FUTURE ORCHARDS

It is to be noted, in conclusion, that changing over, with time, to the third and subsequently even to higher generation seed orchards appears to be the very line tree improvement will take. Selection and propagation within the breeding material available and the establishment of new seed orchards will apparently be done in the future. Of course, the problem of specialization, or, alternatively, universalization suggests itself in this connection. Breeding material of second-generation orchard origin as well as separate selection of forest tree species are likely to be used when establishing third-generation orchards. In the course of implementing tree breeding programs, to meet the needs of the century in the future, one cannot focus exclusively on the specific end uses of today. Stands currently established will reach technical exploitability only after a number of decades for which it is hardly possible to forecast with precision the needs in pulp, saw timber, wood or energy, etc., to say nothing of the whole spectrum of ecological constraints going to be imposed. So, in consequence, a careful preservation of forest genetic resources in all their diversity is felt strongly to be the main task for the future, or, in other words, the process of breeding elite material of tree species is to go hand in hand with an overall preservation of forest germplasm.

IMPLICATION OF MIMOSINE ALLELOPATHY IN AGROFORESTRY

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Samastipur - India

FDC: 181.41: 26: 176.1 Leucaena leucocephala de Wit: 176.1 Vigna mungo

Leucaena leucocephala, is gaining popularity for plantation under agroforestry programmes, owing to its multipurposeness. However, presence of high concentrations of mimosine in its leaves, is a cause of concern. When fed on *Leucaena* meals, the general health and productivity of several domestic animals have been found to be severely affected. However, the possible allelopathic effects of mimosine oh crop plants, is yet to get the deserving attention. Therefore, to look for any such effects, plants belonging to various crop groups were subjected to mimosine treatment. It was found that almost all the crops tested were adversely affected by 1.0 mM of mimosince. Detailed studies were made with *Vigna mungo*. All the parameters studied were significantly inhibited. On the basis of experimental findings, it is suggested that the inhibition of germination and growth of *V.mungo* might have occurred atleast partly, via inhibition of amylase and proteases, the hydrolyzing enzymes. The importance of allelopathy in agroforestry is discussed and its possible benefits are described.

The term agroforestry is internationally used for a suitable land management system which increases the yield of a particular piece of land, combines the production of crops (including tree crops) and forest plant and/or animals simultaneously or sequentially on the same unit of land and applies management practices of the local populations (King and Chandler, 1978). Trees which are recommended for agroforestry system, ought to have some specific characters like, fast growth rate, good forage, food and wood value and morphology which should permit the penetration of light to the ground etc. It has been assumed that viability of the tree - crop association is governed by physical factors, viz., status of light, moisture and nutrients etc. (Melkania, 1983). However, recent researches have provided convincing evidences that apart from the physical factors, the naturally occurring phenomenon of allelopathy may also play crucial role in determining the success of tree - crop/fodder plant association. One of the aspects of agroforestry is mixed cropping of trees with crops. Thus, possibilities are fair that allelochemicals produced by the tree will affect the crops.

Since the idea of agroforestry has been floated, a lot of work has been done. However, the literature seems to be lacking in reports on possible allelopathic interactions amongst crop plants and trees, intercropped under agroforestry programme. Leucaena leucocephala is one of the widely recommended tree under agroforestry programme. It has received much attention due to its leguminous nature, fast growth, nutritive and economic values. Consequently large scale plantation has been done in various countries including India. In fact, in certain instances, Leucaena plantations have increased the total productivity of a particular land, when grown in association with crop plants. However, presence of a nonprotein amino acid - mimosine (α-amino-3-hydroxy-4-oxo-1(4H)-pyridine propanoic acid) in leaves and seeds of L.leucocephala poses great threat to its exploitation in agroforestry programme. The air-dried leaves of various species of Leucaena have been found to contain 2.77 to 5.75% of mimosine (Kuo et al., 1983), which is an appreciable amount to affect the growth of companion crops. Though studied in animals and lower organisms, there are reports that mimosine causes hair loss, induces cataract disease and variously affects the growth of domestic animals (ter Meulen and El-Harith, 1981). Kuo et al. (1983) reported that mimosine completely inhibited cell division and synthesis of DNA,RNA and protein in Paramoecium tetraullia at sub-millmolar concentrations. However, there appears only a few reports on allelopathic effects of mimosine in crop plants. Therefore, we took up the present study to work out effects of mimosine on representative plants belonging to various groups of crop plants and to investigate its effects in detail on Vigna mungo, an important pulse crop of Indian sub-continent.

Effect of mimosine on crops

To study the possible allelopathic effects of mimosine on crop plants, representative plants belonging to pulse, vegetable, cereals and oilseed crop groups, were selected. Effect of 1.0 mM aqueous solution of mimosine on seed germination and seedling growth were studied employing seed germination bioassay as described earlier (Rizvi et al., 1981). In this, the seeds were germinated in petridishes on 2 layers of filter paper with or without mimosine solution. Distilled water was used in control sets. Treatment of mimosine adversely affected all parameters considered in almost all the test crops (Table 1). Amongst the crops tested, Vigna mungo was selected for detailed study.

Studies with Vigna mungo

Except 0.5 mM of mimosine all the concentrations used were found inhibitory to seed germination. Similarly, radicle and plumule length, weight of embryonic axis and seedling vigour were also adversely affected(Table 2). There was 35 and

79% inhibition in dry weights of plumule and radicle respectively. But the dry weight of cotyledons in mimosine treated seedlings was found to be 66% more in comparison to the untreated seedlings. This indicated that mimosine treatment might be affecting the mobilization of the stored food from cotyledons to the embryonic axis (Table 3). This possibility was substantiated from the fact that the food mobilization efficiency of the treated seedlings was found to be 48% less in comparison to the untreated seeds (Table 3). In order to have some idea about the mode of action of mimosine, various analyses were done. It was found that the level of protein in cotyledons of the treated seedlings was always higher in comparison to the seedlings grown from untreated seeds. On the contrary the level of total amino acid was always lower in the embryonic axes of seedlings grown from treated seeds. This might have been caused through an adverse effect on the activity/level of protease, the protein hydrolyzing enzyme. In addition to alteration of protein hydrolysis, seeds treated with 1.0 mM mimosine also showed a marked decline in amylase activity during germination. The decrease in amylase activity was further supported by a higher level of starch and lower level of sugar in the treated seedlings while it was just reverse in the case of untreated seedlings (Table 4). A direct correlation between germination and seedling growth, with that of biochemical analyses, indicated that the inhibition of germination and growth was atleast partly due to inhibition of amylase and reduced solubilization of the stored protein in the cotyledons.

Results presented here clearly demonstrated that the allelopathic compatibility of trees, with food/fodder species should be carefully studied before recommending any specific tree under agroforestry programme. Lastly, it can be concluded that if allelopathic considerations are given due importance it would be useful in following ways:

(i) selection of best suited companion crop/variety

(ii) increasing the production either by minimizing losses due to negative allelopathic effects or through exploiting the positive allelopathic interactions amongst the trees and the companion crops, which would be without increasing the farm inputs.

However, comprehensive research work is needed to extrpolate the laboratory results to the field conditions. Further, considerations of concentrations and persistence of allelochemicals in soil under the action of microorganisms would be a prerequisite to reach any definite conclusion. But the peach replant and citrus decline problems due to accumulation of allelochemicals like, amygdaline and homovanillic acid, respectively in soil (Rice, 1984) emphasize the potentialities of our findings for exploitation in agroforestry.

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Table 1: Effect of 1.0 mM mimosine on per cent increase/decrease of germination, radicle and plumule length of various crop plants

Test plant	Germination	Radicle length	Plumule length
Abelmoschus esculentus	+13	-42*	-38*
Brassica campestris	-42*	-	+12
Oryza sativa	0	-6	0
Phaseolus aureus	-3	-86*	-85*
Vigna mungo	-14	-83*	-47*

*Significant at 5% level.

Table 2: Vigna mungo : Effect of different concentrations of mimosine on per cent inhibition of germination, radicle and plumule length and fresh weight of embryonic axis at 72 hours age

Concentration mM	Germination	Radicle length	Plumule length	Embryonic axis(F.W.)	Seedling vigour
0.5	2	28*	9	6	23
1.0	4	76*	47*	42*	75
1.5	14*	83*	88*	77*	86
2.0	18*	83*	100*	89*	87
3.0	23*	86*	100*	87*	90
4.0	38*	86*	100*	89	92

*Significant at 5% level.

Seedling vigour was calculated using formula SV = % germination x radicle length.

Table 3: Vigna mungo: Effect of 1.0 mM mimosine on dry weight of cotyledon, radicle, plumule and food mobilization efficiency of seedling at 72 hours age

Parameters studied	% inhibition/ induction
Cotyledon dry weight	+66
Radicle dry weight	-79
Plumule dry weight	-35
Food mobilization efficiency	-48

Food mobilization efficiency was calculated using formula:

$$ME = 100 \times \frac{\text{Increase in dry weight of axis}}{\text{Decrease in dry weight of cotyledons}}$$

Table 4: *Vigna mungo* : Effect of 1 mM mimosine on per cent increase/decrease of amylase activity and various biochemical constituents of cotyledon and embryonic axis of seedlings grown from seeds treated with mimosine.

Parameters studied	Age in hours		
	24	48	72
Protein (C)	+21	+29	+25
Amino acid (EA)	-15	-22	-19
Total starch (C)	+19	+25	+20
Soluble sugars (C)	-17	-22	-17
Amylase activity (C)	-25	-31	-22

C = estimated in cotyledons

EA = estimated in embryonic axis.

POPLAR BREEDING IN THE REGIONS OF TEMPERATE CLIMATE OF THE USSR

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FDC: 165.62: 165.41: 176.1 Populus spp.: (47)

SUMMARY

Results of poplar breeding investigations during selection, introduction, hybridization in forest-steppe, steppe and semi-desert zones of the USSR's European part are presented. There have been studied natural form diversity in aspen, white and black poplar in forest-steppe. Economically-valuable forms were selected. On the material of poplar 780 variety x sites there were studied regularities of manifestation for phenological development, growth, resistance and timber quality depending on the origin, ecological conditions of cultivation, systematic belonging and individual pecularities in poplar clones and varieties. Bearers of valuable characters have been determined. They can be used in hybridization and when working out poplar economically valuable assortments. Results of one of the greatest in the USSR programmes on poplar hybridization were presented. During its realization 59000 of hybrid seedlings have been received. After long-term testing 135 best hybrids have been selected among them.

Keywords: poplar, selection, hybridization, variety study, introduction

INTRODUCTION

Poplar is one of the most fast-growing species of the temperate climate. The area of its natural stands in the USSR is 1095000 ha and timber volume - 132 mil.m^3. The area of artificial poplar stands makes up about 150000 ha. It is used for establishment of highly productive plantations, in forest improvement and amenity planting. However, the use of low quality material results in significant loss. From the begining of 1930th a number of researchers of the USSR pay much attention to poplar breeding. These are works of A.V.Albensky, P.L.Bogdanov, A.S.Yablokov, A.M.Berezin, S.S.Piatnitsky, N.V.Starova, G.P.Ozolin, M.M.Veresin, S.P.Ivannikov. P.P.Beschetnov, F.L.Schepotiev, N.A.Konovalov etc. (Старова 1980; Царев 1985). The main aims of their investigations were breeding and selection of fast-growing poplar forms and forms resistant to unfavourable environmental factors. Special attention was paid to breeding of rot-resistant aspen forms, winter- and drought-resistant forms of Eupopulus and white poplars.

From 1960the the authors of the article carry out researches on this problem. The work were conducted in the south-eastern part of the USSR's European territory (USSR ET). They consisted of 3 trends: 1) selection of the best forms in natural stands; 2) introduction of clones and varieties from different USSR's regions and foreign countries, their study and selection of promising assortments for different soil-climatic USSR ET zones; 3) carrying out works on hybridization with the aim of receiving new perspective hybrids for different economic purposes.

EXPERIMENTAL ESTABLISHMENTS AND METHODS

Selection of aspen stands resistant to heart rot (agent is fungus Fomes igniarius Fr.), plus stands and trees of white and black poplars was carried out in natural stands in Voronezh region. Simultaneously with selection, intraspecific variability of poplar species growing in natural conditions was studied. Inspection of aspen stands took place in 7 forests, including Voronezh and Hoper State natural reserves (the total area is 17000 ha). Black and white poplars were studied in Hoper State natural reserve on the area 2500 ha.

Introduction of the best poplar varieties, clones and hybrids have been accomplished from 29 locations of the USSR (Leningrad, Byelorussia, districts near Moscow, the Ukraine, the Urals, Kazakhstan, Middle Asia, Western Siberia, the Far East, etc.) and from Romania. Many varieties and clones have been introduced there earlier from a number of regions of the USSR, some countries of Europe, Asia and North America. The collection comprises about 300 clones. Regions of their origin fromed 6 groups, which correspond to phytochorions of holarctic reign (Тахтаджян 1974): 1. North of the USSR ET, Siberia, the Urals; 2. The central part of the USSR ET; 3. South of the USSR ET, Middle Asia, the Far East; 4. The northern part of North America; 5. The central (western) part of North America and Western Europe; 6. The southern (eastern) part of North America, southern part of Western Europe.

Introduced variety samples were tested in forest-steppe, steppe and semi-desert zones (latitude 46-52° North and longitude 38-48° East) Average annual air temperature on the investigating territory varies from +5°C on the north up to +9,4°c on the south. Average temperature of the coldest month (January) ranges from -10,5 up to -6,8°c, the warmest one (July) reaches +20- +25,3°C. Absolute minimum and maximum temperatures reaches -40 and +40°C. Vegetative period is in average 185 days on the north and 216 days on the south of the region. Average annual quantity of precipitation is 500-180 mm a year, respectively. For variety testing (the results are presented in this work) 28 specially established in different regions plots were used. The total area of the plot was 62 ha. On these plots 780 variety x sites are studying, including 50 white, 67 balsam, 427 black poplars and 236 intersectional hybrids of Eupopulus. Soil of the experimental plots is represented by different zone types such as grey forest, chernozem and light-brown semi-desert in a complex with solonetz. In the conditions of flood-plain alluvial intrazone banding and grainy soils prevail.

In testing the following indices were taken into account: damage by frost, drought, wind, pests and diseases; growth rate, stem and crown form, timber specific gravity, timber length, pulp content, sex, etc. As a rule these indices were analysed depending on provenance, ecological conditions, poplar systematic belonging, their individual pecularities.

Poplar hybridization in the region was started in 1950s by Veresin M.M. on the species level. Male allotriploid e.s.-38 (or "Voronezhsky gigant"), bred by Veresin is widely spread in the USSR. After establishing poplar collections works on hybridization have been expanded in TSNIILGiS. During 1975-1989 44 female and 43 male clones of different poplar sections have been selected for crossings. Within them more than 400 crossing variants were fulfilled, including simple intra- and intersectional, polycross, back, stepwise, clonal-hybrid, interhybrid and intervarietal crossings. Parents were selected both according to the principle of ecologic-geographic remoteness and economically-valuable characters. Among maternal there were selected the most valuable black poplars: Pioner, Regenerata, Marilandika, deltoides, black poplar, I-214, Vartikal, etc., among paternal: Brabantika-175, Robusta, Gelrika, Bakheliery, Sacrau-59, Pyramidal-black Kamyshinsky (PBK), etc. Balsam poplars because of their frost resistance are used for crossings. Among them Californian, balsam, maximoviczii poplars have been selected as maternal forms, as paternal P.suaveolens and Chinese poplar have been used. Within paternal forms producing certain per cent of diploid pollen there were selected A.P.Tsarev's hybrids: Peredel, Ruslan, Prostor, etc. and M.M.Veresin's hybrid e.s.-38 (Мурая 1988).

Crossings were carried out both on cut branches by A.P.Tsarev's (1984) modification and on growing notched trees with film covered stemnotch.Seeds were viable in 113 variants. Their average germination for the period of investigation was 52%. Newly collected seeds were sown in vegetative containers and seedlings were transplanted into the open ground in the nursery.

In all, 59000 seedlings have been received out of which 34000 plants have been transfered into the ground. After 2 year study in the nursery there were selected best hybrids. The hybrids were translpanted to constant plot with spacing 4 x 4 and 5 x 5m.

RESULTS AND DISCUSSION

The study and selection of forms in natural stands

The study of aspen stands' polymorphism allowed to determine availability of forms by phenological development and morphological pecularities. There have been also found out clone differentiation conditioned by sex dimorphism (Царев 1985). Early-, intermediate- and late-breaking forms have been selected. The study in 41-50 year old aspen stands showed that the per cent of damaged stems (with the presence of fungus fruit body) in the stands of late form is about 1,5 times less than in the stands of early form.

By morphological pecularities there have been selected forms with weeping and pyramidal crown form, with straight and crooked stem, with large- and fine-chinked coarse bark, etc.

Smooth-green barked, smooth-grey barked (coarse bark raise up to 3m) and coarse-green barked, coarse-grey barked (coarse bark raise higher than 3m) forms have the most practical value.

The area of male aspen stands is 4,5 times higher than the area of female ones. In drier and poorer sites aspen stands of male sex prevail. As a rule they are less damaged there than female stands. In rich and moist conditions female stands dominate, there they are less damaged than male ones.

Four plus stands of aspen, 3 - of white and 2 - of black poplar (one of which was of burl form) have been selected in the result of investigations. Besides there have been selected 9 plus trees of white poplar and 10 - of black one, including 5 of burl form. In plus aspen stands at the age of 43-46 a number of trees with fruit bodies of false tinder fungus varied from 0 up to 6%, at the same time in ordinary stands it was 21-91%. Timber volume in aspen plus stands was 186-294 m^3/ha. Timber volume in ordinary stands was 10-82 m^3/ha, and the total-274-475 m^3/ha. Selected stands of white poplar were 64-95 years old and of black one - 70 years old. Their average height was 28-42 and 28-30 m, average diameter - 47-82 and 51-52 cm, timber volume - 709-1513 and 414-623 m^3/ha, average increment - 11-16 and 5-9 m^3/ha a year, respectively. Black poplar of burl form has lower parameters. Timber volume for ordinary stands of black and white poplar varied from 195 up to 295 m^3/ha. That is plus stands exceeded ordinary ones in productivity by 2-5 times.

They are of special interest for breeding.

Introduction and variety testing

Investigation of phenological development in introduced poplars showed that clones and varieties, originating from colder continental conditions, start and complete sprout growth and vegetation earlier. They are characterized by shorter vegetation and growth periods in comparison with clones and varieties originating from conditions of warmer and milder climate. Rates of phenological development of the same poplar clones growing in various zones are different. In our test when transfering clones from north-western part of the test region to the south-east (about 1000 km) their vegetation period increased (7-20 days) but the period of sprout growth decreased (12- 19 days). On the contrary when transfering from the south to the north vegetative period decreased (2-6 days) or was the same. The period of sprout growth increased. Earlier start and completion of vegetation and sprout growth periods and their less duration were observed in balsam poplars (in average 145 and 178 days, respectively, for forest-steppe). Black and white poplars were characterized by later growth and vegetation period. White poplars were intermediate. The longest sprout growth (up to 156 days) and vegetation (up to 191 days in forest-steppe) period were characteristic for black poplars. Phenological development in intersectional hybrids of Eupopulus is closer to balsam poplars. Their average date of start and completion for sprout growth and duration of sprout growth and vegetation periods are similar.

The study of growth in height and diameter of different poplar varieties and clones showed that representatives of southern regions in the conditions of temperate climate didn't manifest higher productivity because of low temperatures' overwhelming influence. The growth of introduced poplar clones greatly depends on their systematic belonging and individual genetic pecularities. The best growth both in the south and in the north of the research region manifested black poplars with spreading crown. Average timber volume of these poplars in 15 year old stand (in forest-steppe conditions) reached 310 m^3/ha. At the same time average timber volume of balsam poplars was 195 m^3/ha, white poplars with spreading crown - 188 m^3/ha, white poplars with pyramidal crown reached only 95 m^3/ha. Within the same morphological-systematic group, between various clones there were observed significant differences in growth. Productivity of fast-growing poplar varieties (clones) at the age of 15 was in 2,3 (black poplars) - 9,5 (white poplars with pyramidal crown) times more than the productivity of slowly-growing poplars. In the region there was selected a number of poplar clones with valuable characteristics, concerning growth rate: Regenerata (NN 78,79), Gelrika (NN 21,80), Brabantika-175 (N 158), Brabantika-176 (N 56), Robusta-195 (N 35), Vernirubens (N 54), Bakheliery (N 30), Marilandika-239 (N 34), Evroamerikansky (N 77), etc. At the age of 15 annual average increment in stem volume of these varieties was 41-64dm^3 or 20,5-32 m^3/ha a year (Tsarev et al. 1989).

The study for resistance of poplar clones and varieties showed that depending on geographical origin one may observe the following regularities and trends: a) more winter resistant are varieties and clones originated in more cold and continental climate; b) estimation of drought resistance didn't show such clear regularity but we should point out the tendency of more drought resistance among clones and varieties of southern origin; c) damage by primary and secondary pests didn't show reliable relation with the clones' provenance; d) damage by rust and diseases rather clearly depended on the origin, it's less in varieties and clones of southern origin and higher in ones of nothern origin. When transfering varieties from the south to the north there observed increase in their damage by winter frosts up to the death, when transfering from the north to the south damage didn't increase with the exception of drought influence cases. When transfering varieties from the south to the north the damage by summer drought is lower (by 0,2-1,0 points), and when transfering from the north to the south - it is higher (by 1,1-1,7 points). Damage by primary and secondary pests (in the region under study) doesn't show so clear regularities depending on cultivation geography; however in unfavourable ecological conditions poplars are more damaged by pests than in optimum conditions. Damage by rust and other diseases in poplar clones is higher in the north of the investigating region than in the south; when transfering them from the south to the north from drier to the more moist districts damage degree in the same clones and varieties increased; and on the contrary, when transfering from the north to the south it decreased. Some diseases my have another character of their manifestation.

Depending on systematical belonging of clones and varieties, their resistance character is revealed in the following way: a) balsam poplars have the highest winter resistance; black and white poplars with spreading crown are less resistant; and white pyramidal poplars are the least resistant; b) white pyramidal poplars are the most drought resistant, black ones are less resistant and balsam poplars are the least resistant to drought; c) the most wind damaged are varieties and clones from the group of balsam and intersectional hybrids of Eupopulus (10-34% of trees), more resistant are white poplars with spreading crown and black ones (up to 0,2% of damaged trees); d) white poplars are less damaged by primary pests in comparison with Eupopulus and their hybrids; secondary pests harder damaged balsam poplars and white with pyramidal crown and less - white and black poplars with spreading crown; e) the least rust damage is determined in white poplars, the highest - in balsam and intersectional hybrids of Eupopulus and intermediate - in black poplars.

Whithin the same morphological-systematic groups in similar conditions there was observed significant variation of resistance in poplar clones and varieties depending on their individual pecularities, conditioned by gene type. This made possible to select poplar varieties and clones with valuable resistance character. The most frost resistant poplars were: suaveolens (NN 99, 100), balsam (x_6, x_8), Moscovsky (N 101), Ivanteevsky (NN 46, 47, 82, 109), Nevsky (N 105), Voronezhsky gigant (NN 46, 94), P.trichocarpa (N 135), Pioner (N 26) and others; the most drought resistant poplars were: Pervenets Uzbekistana (N 124), PBK (N 167), Robusta (NN 163, 127), Bakheljery (N 112), Regenerata (NN 20, 79, 126), Gelrika (N 80), Brabantika-176 (N 36) and others; the most winter resistant poplars were: Bolle (NN 137, 144, 145), Sovetsky pyramidalny (N 125), white (NN 143, x_7), aspen (x_2), Pioner (N 42), PBK (N 91), Leningradsky (N 104) and others; the most rust resistant poplars were: Bolle (NN 144, 145), Sovetsky pyramidalny (N 125), Stremitelny (N 123), Pervenets Uzbekistana (N 124), white (N 143), black hybrid e.t. 98 (NN 2, 29, 121), black hybrid e.t. 120 (NN 4, 28), Robusta-162 (NN 1-22), P.simonii (N 133) and others.

The study of timber quality allowed to establish a number of regularities and to select clones distinguished by straight stem, high timber specific gravity and pulp content and by long timber fibres (Царев 1985).

Hybridization

Poplar hybridization was carried out in 2 stages. At the first stage (1975-1978) crossings were carried out on introduced clones and hybrids selected in TSNIILGiS collections. Growth analysis of 12-year old hybrids allowed to select the best progenies of the families N 75.52 (P.trichocarpa x e.s. - 38), N 57.33 (balsam x PBK), N 75.19 (P.deltoides x PBK) out of 21test families of Eupopulus and white poplar. These progenies were the best by biometric parameters and resistance to climatic conditions. Average hybrids' height of the named families in dry growth conditions (D_{1-2} by P.S.Pogrebnyak) was 11-13 m, average diameter - 16-22 cm, average volume of stem timber - 125-240 dm^3. In the control all these parameters were lower, 10 m, 16 cm, 120 dm^3, respectively. Hybrids of the family N 76.B.31 (white x Bolle) at the age of 12 years had average height - 13 m, diameter - 18 cm, stem volume - 183 dm^3.

Hybrids (received in 1977) at the age of 10 years had mean height - 8,4 m, diameter - 12,5 cm. The best families were N 77.13 (P.trichocarpa x P.balsamifera) and N 77.51 (P.deltoides x PBK), their parameters were 9,0-10,4 m and 14.15 cm, respectively. Progeny of the families N 75.31 and N 77.31 (P.balsamifera x P.balsamifera) was the worst in growth. The average height in 12 year old hybrids was 8,5 m, diameter - 14 cm; in 10 year old - 5 m and 6,5 cm, respectively. 85 perspective hybrids from 16 families have been selected in the result of progeny test of the first hybridization stage. Hybrids of black poplars Stepnaya Lada and Rossiyanka had the best growth (height - 13-15 m, diameter - 29-31 cm, stem volume - 450-455 dm^3). Intersectional and complex hybrids Stroin, Bylina and N 75.52.-33.03 were somewhat inferior in diameter increment (14-16 m, 24-25 cm, 300-343 dm^3). White poplar hybrids Veduga and Bolid by their growth parameters are similar to black hybrids (15-15,5 m; 23-26 cm,; 339-392 dm^3). In addition they posess high decorative qualities and don't have seeds.

At the second stage of hybridization not only parents (introduced from different points of the USSR), but the best hybrids, received at the first stage, were included into crossings. Seed collection from some maternal trees (half-sib progeny) have been carried out besides controlled crossings. At this stage the work was carried out only with Eupopulus.

Analysis of the results for the second stage of hybridization allowed to reveal easily crossing parent poplar forms, i.e. out of maternal: Pioner, Ivanteevsky, black, Addita, Regenerata, Marilandika and others; out of paternal: e.s.-53, Nevsky, suaveolens, PBK, Krasnonervny and others. Somewhat worse crossability there had female forms of P.trichocarpa, P.deltoides, P.maximoviczii; male froms of poplars: Robusta, Brabantika-175 and complex hybrids. Poplars I-214, I-455, Sacrau-79, e.s.-38 and others had poor crossability or didn't give progeny at all in the controlled pollination conditions.

Growth analysis of hybrid families and some forms of the second hybridization stage was carried out. The most seed and seedling yield and survival on a constant place were in the following families: Pioner x Nevsky, Pioner x e.s.-53, Ivanteevsky x P.suaveolens and Addita x e.s.-53. However, it is advisable to judge about hybridization effect of poplar by progeny growth and quality. Reliably best in growth were progenies of families Pioner x P.suaveolens, P.maximoviczii x Brabantika-175, half-sibs of poplar Pioner x P.maximoviczii. The average height for hybrids of the named families at the age of 6 years was 6,4-7,2 m; diameter - 7-9 cm. In the conrol these parameters were lower - 5,2 m and 6 cm, respectively.

At the present testing stage 50 best hybrids of 19 families have been selected in the collection for propagation by a number of characters (Царева 1988). Average height for the group of selected hybrids varied from 6,5 up to 9 m, diameter - from 6 up to 13 cm. The largest hybrids (height - 8,5-9,5 m, diameter - 9-16 cm) were selected in the families by distant hybridization: Pioner x suaveolens, Pioner x Nevsky, Pioner x e.s.-53, P.maximoviczii x Brabantika-175 and among half-sib progeny of poplar Pioner and P.maximoviczii. Best hybrids of the family Ivanteevsky x P.suaveolens (8,2 m, 13 cm) are similar to the latters. Especially distinguished in the group of promising hybrids of the second hybridization stage are 2 male half-sibs of poplar Pioner (9,5 m, 16,6 cm) and P. maximoviczii (8,6 m, 13,4 cm). They exceed the mean combined values for testing hybrids in height by 1,6-1,8 times, in diameter - by 2,3-2,9 times.

CONCLUSIONS

Summarizing the results of the investigations the following conclusions can be drawn.

- Carried out investigations allowed to select and to preserve economically-valuable gene pool of poplars successfully growing in temperate climate of the USSR.

- Established regularities in phenological development, growth, resistance and timber quality, depending on geographical origin, cultivation region, systematical belonging and individual pecularities of poplar clones, hybrids, forms and varieties allow to select bearers of economically-valuable characters purposefully and to recommend promosing forms for assortments in concrete growing conditions.

- The use of hybridization method allowed to specify some ways for increasing the efficiency of hybridization process, to establish some regularities in inheritance of parent characters and to receive poplar hybrids combining economically-valuable qualities of initial forms.

- Continuous change in industrial demands, the rise of new pathogene and pest races, change in ecological situation, the use of polyclonal method for the raise in resistance of establishing stands and other factors require constant renewing and enlarging of assortment. In connection with this it is necessary further development of breeding and introduction work, including the use of different new and traditional methods of selection, hybridization, mutagenesis and others, both separately and in combination.

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OBJECTIVE MEASURES OF TREE HEALTH IN THE FIELD

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SUMMARY

Recent declines in forest vitality in central Europe and eastern North America have promoted interest in methods of assessing tree health. The Europe-wide surveys of tree health using common protocols rely on visual assessment of symptoms of symptoms in the field. Methods for extending such surveys by using quantitative objective measurements to detect deterioration in tree health before visible symptoms appear are discussed, using physiological measurements of stress responses in trees as examples. Current developments in technology promise the possibility of making useful measurements of tree health in the field.

INTRODUCTION

What do we mean by 'tree health'? There are a number of different aspects of tree health which must be addressed before embarking on a programme of measurements. What are we trying to measure, and why? The question 'why?' could be based on economics, seeking information on timber yield and quality in a plantation forest, or could be based on conservation interests, seeking information on the stability of a natural forest ecosystem. More commonly, the reasons for seeking information on tree health encompass a range of motives, and are stimulated by perceived changes in the visible condition of forest trees. In many cases, the cause of a deterioration in visible condition may be obvious (eg insect defoliation), and the choices of management strategy to be adopted to alleviate the problem are well defined. In others, simple diagnostic indicators (eg foliar nutrition) may suggest a management strategy for amelioration, or may identify the cause of the problem (eg pollutant emissions from a point source).

However, difficulties arise when there is a perceived change in the visible condition of trees, if there are no obvious causal factors involved, and if recovery does not appear to be occurring. The phenomenon of forest 'decline' is not new, and has been well described by Manion (1981). Recent widespread 'declines' in forests of central Europe, N.E. United States and eastern Canada have stimulated interest in methods for assessing tree health, not least in response to public concern and the need to document the progression, or otherwise, of these 'declines'. In this case, the question 'what are we trying to measure?' is answered in terms of the visible symptoms of decline: premature loss of foliage and leaf discoloration. The major international surveys of tree health in Europe, operating to a standard protocol (Anon, 1987), rely on visual observation and assessment of tree crowns. No attempt is made to assess reductions in productivity or subtle changes in forest ecosystems. The simplicity of the European monitoring survey means that it can be applied economically across European forests, but also means that the results are necessarily rather crude and can give no indication of causes and effects. It may well be successful in showing temporal and spatial changes in visible symptoms, but cannot be expected to do other than suggest possible hypotheses of cause and effect for further investigation.

OBJECTIVE MEASURES

One of the biggest problems with the current UNECE protocols for assessing forest health in Europe is that they have been defined in terms of visible symptoms of decline. As these are dependent on human observers, a degree of subjectivity is present in any assessment. Rigorous training of observers has led to improvements in the quality of survey data (Krause et al, 1986) but the overall classifications of damage used in the survey (Table 1) are still rather broad (Hanisch & Kilz, 1988). In practice, this may not be important in evaluating temporal trends, but problems arise when estimating spatial variability across a wide latitudinal or altitudinal range. In many cases it is not possible to define what is the 'normal' growth form or leaf retention for a tree at a given site, against which to assess the extent of visible symptoms. In the European survey a standard set of photographs is used, which can lead to apparent 'damage' symptoms being recorded in regions where the 'normal' growth form is different from that shown in the picture. Inevitably, the existence of data showing spatial and temporal differences in apparent tree health leads to questions of causes.

Table 1 Criteria used under the UNECE protocol for visual assessment of damage.

- Grid 16 km x 16 km intersecting with woodland area >0.5 ha.

- Results reported for 5 most important broadleaved species and 5 most important conifer species.

- Crown density (leaf loss) expressed in 5 categories:

0	0-10%	no damage
1	11-25%	indicative
2	26-60%	moderate damage
3+4	>60%	severe damage & death

- Discoloration expressed in 4 categories

0	0-10%	none
1	11-25%	indicative
2	26-60%	moderate
3	>60%	severe

Improvements to the current system, to include an element of diagnosis, have been suggested. For example, trees could be surveyed twice a year rather than only once, in summer, to gain information on the development of pathogen-related symptoms, in an attempt to explain why trees may have shed leaves prematurely. It is difficult to determine the causes of premature leaf fall after it has happened. More generally, attempts at diagnosis have also sought to identify parameters which would give indications of deterioration before the onset of visible symptoms, thereby identifying individual trees or areas of forest 'at risk', without necessarily defining the causal agent(s). Such an extension of tree health surveys to include 'early diagnosis' requires the existence of quantities which can be objectively measured in order to determine a scale of damage which progresses from none, through a 'latent' phase, to the expression of visible symptoms.

A wide range of potential diagnostic tests for the identification and early diagnosis of forest decline symptoms has been explored (Cape, 1988), both by individual research groups comparing 'healthy' and 'damaged' trees of a single species within a single site, and by multi-disciplinary international studies covering one or more tree species across a range of sites. In many cases, such diagnostic tests have been based on the supposed causal relationship between effects and one or more forms of air pollution. In practice, however, specific responses are rarely found, and many of the tests employed measure the general stress response of a tree to its environment, without giving much information on the likely underlying causal mechanisms. Objective tests for measuring tree health in this way have been classified by scientific discipline (Table 2), but it may be more useful to draw a distinction between measurements of status and measurements of function.

Table 2. Methods for investigating the effects of air pollutants on trees (after Cape, 1988)

microscopic -	external surfaces cell ultrastructure
'whole leaf' -	electrolyte leakage element composition

external surfaces -	leaf wettability amount and composition of surface wax Härtel turbidity test
physiological -	photosynthesis/respiration water relations
biochemical (non-destructive) -	reflected light (remote sensing) induced fluorescence electron paramagnetic resonance nuclear magnetic resonance emission of organic compounds
biochemical (destructive) -	enzymes and substrates/precursors pigments other metabolites buffer capacity
roots -	elemental analysis mycorrhizal associations

Measurements of status record the actual condition of the tree at the time of sampling. The underlying dynamics of the measured parameter should be understood in order to interpret the results; the seasonal pattern of foliar nutrition for Norway spruce, for example, is fairly well documented (eg Wyttenbach & Tobler, 1988) and measurements of nutrient status would usually be made after needle expansion was completed, when nutrient levels were relatively stable. Measurements of shoot water potential similarly show well defined diurnal variations, which must be considered when making field measurements. Similar considerations apply for measurements of pigments or primary products of metabolism. Measurements of function, however, rely on evaluating the capacity of the tree to respond to an imposed controlled environment. Short-term temporal dependence is minimised by standardising the factor(s) known to affect the response. A simple example would be measurement of photosynthetic capacity at light and/or CO_2 saturation (Zimmermann et al, 1987) but more complex assays have been used to determine rates of ethylene emission (Wolfenden et al, 1988) or the degree of frost hardiness (Murray et al, 1990) as measures of function. Some of these will be discussed below. More information on sites of dysfunction within the plant, and possible causal mechanisms, may be obtained by detailed histochemical examination of tissue (eg Fink, 1988), but methods for objectively quantifying ultrastructural information have still to be developed.

FIELD SURVEY

One of the good points of the European survey is that it is relatively straightforward (Panzer, 1988) and provides an integrated assessment of the whole tree crown. Making objective measurements requires that attention be paid to sampling strategy. If one is interested only in comparing trees within a given stand, then factors such as aspect and tree age may be well defined and consistent across the stand. However, if one hopes to make quantitative comparisons between stands, or indeed between regions or countries, then the sampling procedure must be well defined. Factors to be considered when sampling foliage are the aspect of the stand, position within the stand, dominance of the tree, age of the tree, position within the crown, age of foliage etc. If sampling across a range of altitude or latitude then phenology must also be taken into account, in addition to the shorter-term temporal variations which may affect the parameter to be measured. Combining such theoretical constraints with the practical difficulties of sampling mature trees in forests inevitably results in compromises, which should be explicitly recognised.

STRESS PHYSIOLOGY

Amongst the many varied measurements, biochemical, physiological or physicochemical, which may be made on trees to assess their state of health are a number which are related, directly or indirectly, to the functioning of physiological processes. Although many types of 'physiological' measurements have been used to indicate responses to stress under controlled laboratory experiments, there have been few applications in surveying tree health in the field. To illustrate the types of measurement which might be made as part of such a survey, let us consider two areas: water relations and photosynthesis.
The measurements should be aimed at properties which determine the functioning of the tree, ie directly related to a specific physiological process. In order to evaluate a given measurement for field use, the following questions must be borne in mind:

- what is the time dependence of the measurement: years, months, days, hours?

- can short-term changes be avoided by using controlled conditions in the field?

- must measurements be made in the field or can tissue be transported to a laboratory?

- if samples are taken for later analysis, what storage conditions must be maintained?

WATER RELATIONS

Transmission of water by tree stems: water supply

The capacity of the trunk to conduct water (and nutrients) between the rooting zone and the crown has been assessed using measurements of cambial electrical resistance and sapwood area. Measurements of the electrical resistance of cambium are readily made under field conditions. A clear relationship with needle loss in Norway spruce has been demonstrated (Garrec et al 1988), and studies to investigate dependence on factors such as stem diameter are in progress. Sapwood area can, in principle, be estimated from increment cores, and has been suggested as an indication of tree vigour through the use of allometric relationships (Waring, 1989).

Water in foliage: control of water loss

Changes in water content of foliage, and the factors which control a plant's ability to regulate its water use, have been used in many studies of plant response to environmental stress. Measurement techniques cover a wide range from simple ratios of leaf dry weight to fresh weight, to estimates of water and solute potential and measurement of transpiration rates.

Absolute amounts of water in leaves vary diurnally, and in response to soil water status, so that quantitative comparative measurements at different times and places are not possible. However, comparison of dry weight/fresh weight ratios of different year classes of Norway spruce needles has been shown to be closely related to visible damage symptoms, and may be used to predict degrees of damage (Mehlhorn et al, 1988). Such differences in water content between different age classes of conifer needles may reflect alterations in stomatal function or cuticular integrity in response to environmental or nutritional factors. Changes in the ability of plants to control water loss have been estimated by measuring rates of water loss of excised leaves under varying experimental conditions. One of the simplest techniques is to allow samples of conifer needles to dry under ambient conditions, water loss being determined by measuring rates of weight loss. Results for different year classes are reported relative to current year needles in order to normalise for variations in temperature and relative humidity during drying (Kylin, pers. comm.). Water loss from excised leaves, expressed as a percentage of saturated water content, has been used to demonstrate effects of air pollutants on stomatal function, where 'treated' and 'control' leaves are compared using standard drying conditions (Neighbour et al, 1988). For use as a survey technique in the field, drying conditions must be standardised across sites so that absolute rates of drying can be established. In principle, leaf drying curves have two phases, an initial rapid loss until stomatal closure occurs, followed by a much slower rate of water loss corresponding to cuticular (uncontrolled) transpiration. Under carefully controlled conditions the two processes may be separated, and information is gained not only on rates of cuticular transpiration (which may reflect cuticular integrity, or non-closure of stomata), but also on stomatal function, by estimating the point at which stomatal closure occurs. Such measurements, conducted under standardised conditions of temperature and relative humidity, could be adapted for field surveys using excised material to give comparable quantitative data. The units of measurement should also be standardised; results have been expressed in terms of leaf area, leaf dry weight or relative to saturated water content. The last of these is perhaps the easiest to evaluate for routine use. Further refinements to the technique may be devised to give absolute measures of cuticular resistance (e.g. Cape & Fowler, 1981), but these require knowledge and control of the drying conditions, and measurements of leaf area, which can be tedious for conifers. However, cuticular resistance has been shown to be closely related to changes in cuticle structure (Crossley & Fowler, 1986) and wettability and measured absolute values could in principle be used in modelling the significance of this pathway of uncontrolled water loss to plants under drought stress.

Measurements of shoot (or leaf) water potential also provide information on plant status, but are dependent on short-term variations in environment, and so are not generally useful for field surveys. However, simultaneous measurements of osmotic potential may give an indication of the degree to which osmoregulation can occur. There is evidence that such information can be obtained for Norway spruce, and related to symptoms of decline (Rosenkranz et al, 1989). More generally, detailed analysis of pressure-volume relationships (Kim & Lee-Stadelmann, 1984) could be used in the field to give information on cell wall elasticity, which has been shown to respond to air pollution exposure (Eamus et al, 1989). Portable pressure bombs have been developed for field use (see e.g. Cape et al, 1988, p 51) but have not been widely used.

Water use efficiency, as a marker of tree health, integrates the effects of several physiological processes, and may be estimated from measurements of carbon isotope ratios. Fractionation of the stable isotopes ^{12}C and ^{13}C is dependent on the ratio of internal CO_2 concentration to external CO_2 concentration, and therefore integrates the effects of physiological variation in stomatal closure etc. (Farquhar et al, 1982). Relative enrichment of the heavier isotope may be used to indicate exposure to stress (Francey & Farquhar, 1982). Historical information may also be deduced from isotope ratios in tree rings (Fry, 1989), but the technique is currently rather expensive for routine survey work.

PHOTOSYNTHESIS

Rates of fixation of carbon dioxide by foliage are very sensitive to environmental stress, have an immediate impact on all aspects of plant growth, and are relatively easily measured. From the point of view of estimating tree health, however, the rapid response to external stimuli is a disadvantage if actual rates of photosynthesis are measured in the field. Progress may be made by controlling the conditions under which photosynthetic rates are measured in the field, by providing constant light, temperature and CO_2, or by providing a degree of control to enable responses to light and/or carbon dioxide concentrations to be measured dynamically (eg Zimmermann et al, 1987). In this way, photosynthetic capacity can be detemrined, and for conifers the change with needle age may also be established. These techniques are currently being developed by a number of groups in Europe to evaluate the possibilities of surveying photosynthetic capacity in the field. The other technique which is being developed, and has been applied to a limited extent in the field, is chlorophyll fluorescence spectroscopy (Lichtenthaler & Rinderle, 1988).

The pattern of chlorophyll fluorescence is affected by drought and nutrient stress as well as exposure to air pollutants such as ozone (Barnes et al, 1988). Although it is a non-specific response under field conditions, attempts have been made to use modulated fluorescence in the field as an indicator of stress (Cape et al, 1988, p33). The interpretation of the fluorescence kinetics is not well understood (Heath, 1989), but as a rapid, portable and potentially non-destructive measurement, its use in the field should be further developed.

CONCLUSIONS

In deciding how objective measurements of tree health may be made under field conditions, it is important to establish what it is that is to be measured. Are we interested in the leaf, the branch, the crown, the whole tree, the stand or the whole forest ecosystem? Current surveying techniques operate at the level of the tree crown, using visual estimates of symptoms. Most measurement techniques operate on the level of the branch, shoot or leaf. This leads to practical problems in statistical design and sampling strategies. For surveys of tree health it is not necessary to estimate integrated values for whole tree crowns provided measurements can be made under strict protocols which ensure comparability of sampled material. Variation within a tree, for example several year classes of needles in conifers, may even be deliberately exploited to produce internal comparisons or ratios. These may vary less with external environmental fluctuations than individual measurements, and may permit simple measurements to yield useful predictive data (eg Mehlhorn et al, 1988). Inevitably there is a conflict between the desire for measurements which point to mechanisms of tree stress, but which are expensive in terms of equipment or manpower, and simple measurements which may give quantitative data on tree health but little indication of causes. Improvements in the portability of equipment for measuring not only the actual rates of physiological processes in the field but also the potential rates under controlled conditions will lead to a greater emphasis on using measures of tree function rather than tree status. The interpretation of such measurements will still require care. Although it is an attractive idea that measurements of tree health should be related to the physiological processes which control tree growth, these very processes may be dependent on other factors which are more easily measured. It is clear that 'Type I' symptoms of spruce decline in central Europe are related to deficiency of magnesium (Roberts et al, 1989), and mineral nutrition has been implicated in the decline of Red spruce in eastern North America (e.g. Friedland et al, 1988) and sugar maple in Canada (Hutchison, pers. comm.). The whole concept of nutrient 'balance' is worthy of further research, particularly in relation to micronutrients such as manganese and zinc.

Finally, however, the development of objective measurements of tree health in the field will depend upon the perceived need for tree health surveys which go beyond the present level of commitment. If one only wishes to map 'decline' in terms of visible symptoms then there is little need for more complex and expensive methods. However, if one wishes to assess the risk of damage in marginal areas (ie before visible symptoms appear), and to get nearer to a diagnosis of the problem, then objective quantitative measures will be required. To date, such detailed measurements in the field have not in general been co-ordinated, with common sampling strategies or monitoring protocols. If progress is to be made in comparing forest decline phenomena across continents, then a concerted approach is needed, building on the lessons learned from the past ten years of intensive research into 'neuartige Waldsterben'.

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HEAT: THE NEGLECTED STRESS

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Heat tolerance has not received a great deal of attention from forestry scientists, especially in comparison to the amount of research on cold and drought tolerance. However, it was well documented in the 1920's and 1930's, that heat damage can cause significant losses of young trees and seedlings.

Our investigations have shown that foliar heat tolerance varies according to several factors, among which are: state of growth, temperature, nutrition, time of day, and clone. Differences in heat tolerance between dormant versus actively growing black spruce seedlings show that dormant seedlings are by far more resistant to heat damage, a trend which matches the seasonal patterns in heat tolerance.

Heat tolerance can also be affected by nutrition and temperature. A three-week-long temperature and nutrition treatment resulted in wide differences in the heat tolerance of black spruce and jack pine seedlings. For black spruce, high temperatures (30°C/20°C, day/night) produced seedlings which were the most heat tolerant. Seedlings kept at lower (15°C/10°C, day/night) temperatures were less heat tolerant. There were no differences in heat tolerance of black spruce which could be related to nutrition. For jack pine, three weeks at lower temperatures resulted in greater susceptibility to heat damage regardless of nutrient regime, while at warmer temperatures there were differences in heat tolerance related to nutrition, where seedlings which were fertilized most heavily were least heat tolerant.

A daily rhythm in heat tolerance has also been found. Black spruce seedlings were most susceptible to heat damage in the morning and late afternoon, with an increase in heat tolerance through the afternoon, from about 1:00 pm to 3:00 pm.

Clonal variability in heat tolerance was demonstrated using black spruce propagated from cuttings. The existence of clonal differences in heat tolerance could be used as a basis for early selection. The propagation of heat tolerant clones for reforestation might reduce damage and increase survival in plantations.

It has been known since the mid-1950's that heat tolerance of plants increases after exposure to moderately high temperatures, and is known as the heat shock response. We have confirmed the heat shock response in black spruce, white spruce and jack pine. The optimum heat shock treatment entailed exposure to temperatures of 38°C to 40°C for three hours per day for six days. Heat shock-treated seedlings have been found to retain higher levels of tolerance than non-treated seedlings for up to 14 days after the last treatment. Research is continuing to further identify factors which affect heat tolerance in trees.

STRESS AND SEEDLINGS: CONCEPTS AND ASSESSMENT TECHNOLOGY [1]

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FDC: 181.525: 181.2/181.3

INTRODUCTION

How do you perceive a seedling? How it is perceived will influence how it is treated. How it is treated will determine the level of stress it must endure. Quantifying stress and the impact it can have on seedling survival and growth is a critical step toward development of a cost effective preventative stress management program.

Technology is creating an opportunity for researchers to pinpoint the source of individual stress events inherent to operations. Once identified, the operational practice can be modified to minimize the stress. A cost effective monitoring program can then be established to help ensure that an acceptable level of seedling vigour is maintained throughout the reforestation process. As we continue to learn about the relationships between seedling development and stress, we will be in an increasingly favorable position to manipulate without stressing, and/or stress proactively by application of pre-conditioning techniques.

The purpose of this paper is to present the fundamental concepts of seedling stress, identify practices that stress seedlings, and document tools for measuring stress response. It is our intent to alert scientists to the opportunities that exist for applying/developing biochemical or biophysical techniques for use in reforestation stress management programs.

THE FUNDAMENTALS OF STRESS IN SEEDLINGS AND TREES

There are numerous situations between cone collection and seedling establishment where stress to seed or seedlings can occur. When the seed or seedling is stressed, it shifts its priorities from the metabolic processes of development and growth to those responsible for adjustment and repair (Bazzaz, et.al. 1987). The shift involves changes in gene expression at both the transcriptional and translational level (Sachs and Tuan-Hua 1986), as well as an array of latent responses involving secondary messengers, hormones, and membranes (Boss & Morré 1988).

Recovery to the pre-stressed condition requires time, energy, substrates for repair, and the absence of further stress events (Chapin III et.al. 1987). Unfortunately, during the reforestation process the potential for stress events is high (DeYoe 1986; Duryea 1985).

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[1] The work herein represents the thoughts and research of a growing consortium of scientists in western Canada and the United States. The author's research was supported by FRDA while Program Physiologist at MacMillan Bloedel, Nanaimo, BC. Research support for other Canadian scientists is also principally through FRDA grants.

Stress Factors and Seedling Response

Stress events registered by the seedling reflect imbalances and/or extremes in temperature, water, light, nutrients, soil and atmospheric chemistry, and physical conditions (Levitt 1980). These "signals" are mediated by the intensity, duration, frequency, and/or timing of the stress event. The initial impact on the seedling occurs at the cellular level, where the signal is received, translated into plant language, and verbalized as a "stress" response.

Stress is cumulative and individual stress events, which can be quite subtle, will diminish the seedling's ability to respond to subsequent events until the seedling has recovered fully from prior stress. Further, if multiple stresses are involved, e.g. drought, high light intensity, and acidic soils (nursery or field), then a condition of chronic stress may develop. Recovery, sufficient to resume development and growth, will take considerable time, and may not be forthcoming until one, or more, of the stresses is alleviated (Gale and Zeroni 1985).

Stress During the Reforestation Process

Maintaining seed and seedling vigour during culture, handling and establishment will improve survival and growth. However, links in the 'handling chain' weakened by poor planning will increase the likelihood that stress inherent to the planting site will be detrimental. Site-related stresses are expensive to minimize, difficult to predict, and become increasingly hazardous to the seedling as site quality deteriorates. Most stresses arising from improper silvicultural practices are subtle (Table 1), the seedling appearing perfectly healthy until after planting, when site factors assist in expressing seedling status. Precautions for maintaining seedling vigour must begin during culture and continue through planting; otherwise, the risk of failure will be high, even on mild sites (DeYoe 1986; Duryea 1985; Chapin III 1985).

TABLE 1: Types of seedling stress and operational situations in which stress can occur.

Frost
- late fall freeze that kills stem or roots
- freeze-storage without proper freezing or thawing technique
- freezing during site storage on upper-elevation sites

Desiccation
- root drying during lifting, temporary storage, and processing
- drying due to vapour loss through holes in bags
- condensation on inner surfaces of boxes in response to evaporative losses from heating during handling

Flooding
- transient waterlogging in container cavities during culture
- exposure of roots to excess moisture in planting bags
- prolonged root dripping

Physical Abuse
- disease during culture
- simple handling of seedlings when stress resistance is low
- root damage during lifting or processing
- jarring or shaking of bags/boxes during transit
- slapping roots against an object to remove soil or ice prior to planting

Heating
- faulty cold storage facilities
- transportation without refrigeration
- local storage without refrigeration
- transport to the site without proper insulation from radiation or heat sources

The Seedling — A Complex Organism

The problem confronting us now is perception. We simply need to understand stress in a tree seedling better. We need to know what constitutes a stress event, what is required for recovery, and how to revitalize or resynchronize the seedling developmentally. Being aware of stress and how it affects plants is the first step (Levitt 1980).

Figure 1 depicts a plant cell in cross section (Lehninger 1982). The cell wall provides the skeletal structure to each cell that supports vertical growth. Inside the wall is the cell membrane which confines the cell solution. The cell solution, or cytoplasm, contains a variety of ions and solutes, important cell regulators (DNA, enzymes, pigments, etc.) and membrane bound organelles. Key organelles include: a) the nucleus, source of genetic information; b) the chloroplast, where light energy is converted into chemical energy the plant can use to produce food; c) the mitochondria, where food is processed to generate energy and heat; and d) the vacuole, where components, potentially toxic to cytoplasmic regulation, are housed. Embedded in the cell and organelle membranes are 'transporters', proteins that control cellular traffic and energy flux.

Signals and Responses - How the Seedling Copes

The signals to which the seedling responds are represented by the chemical and physical characteristics of its immediate environment. The signals "inform" the seedling of minute to minute changes in the environment, so that it can continually adjust and maintain efficient daily operation (Figure 2). They provide early warning of impending seasonal trends in the environment, allowing seedlings to prepare for major shifts in climate. The seedling can also adjust quickly to avoid or tolerate, within limits, extremes in these environmental signals (Levitt 1980).

FIGURE 1: The plant cell and critical cell regulators.

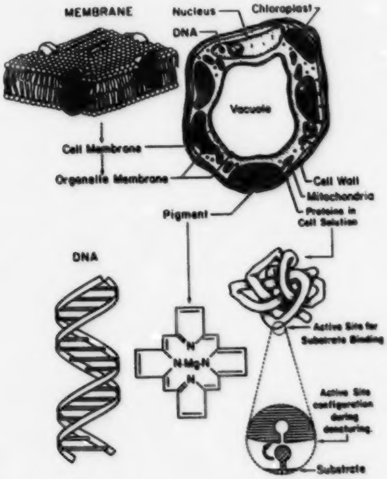
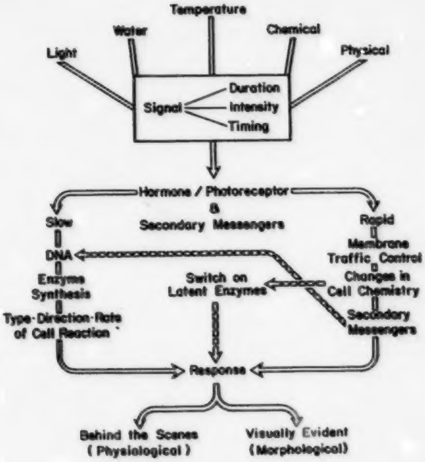

MEMBRANE
Nucleus
Chloroplast
DNA
Vacuole
Cell Membrane
Organelle Membrane
Cell Wall
Mitochondria
Proteins in Cell Solution
Pigment
DNA
N
N-Mg-N
N
Active Site for Substrate Binding
Active Site configuration during denaturing.
Substrate

FIGURE 2: The 'signal -> response' pathway.


Temperature
Water
Chemical
Light
Physical
Signal
Duration
Intensity
Timing
Hormone / Photoreceptor
&
Secondary Messengers
Slow
Rapid
DNA
Membrane Traffic Control
Enzyme Synthesis
Switch on Latent Enzymes
Changes in Cell Chemistry
Type-Direction-Rate of Cell Reaction
Secondary Messengers
Response
Behind the Scenes (Physiological)
Visually Evident (Morphological)

Coordination within the seedling is mediated by cell regulators. These regulators respond to environmental signals and help facilitate the physiological and morphological changes that enable the seedling to cope with its dynamic environment. The cell regulators that respond to specific qualitative and quantitative aspects of environmental cues, and are most sensitive to stress, include: membranes, proteins, DNA and pigments. Figure 2 depicts how these regulators, along with hormones and secondary messengers, fit into a "signal to response" pathway.

Cell Regulators: Function and Consequence of Stress

It is important to understand the role of cell regulators and their sensitivity to stress so researchers can focus their efforts on tools that provide optimum interpretive value. Further, as our tool kits and monitoring programs become more dynamic, we will become more knowledgeable of seedling development/stress interactions, and increasingly proficient at judging stressful conditions and predicting seedling performance.

The membrane is responsible for cell compartmentalization and regulates what goes in and out of the cell or organelle (Mullins 1981). Compartmentalization is achieved by the thermodynamic nature of the fluid lipid membrane bilayer. The lipid matrix is permeable to water, gases, and a few ions, but limits passage of all other components. Transport specificity is achieved by protein transporters embedded in the membrane. These transporters help coordinate the flow of ions, solutes, and cell regulators in response to external and internal signals. Certain proteins associated with membranes facilitate energy conversion or transfer in conjunction with their transport capacity. When lipid or protein components of the membrane are altered by stress, changes in permeability modify cell or organelle chemistry which can have a pronounced effect on the direction of cellular metabolism and/or cell integrity (Mullins 1981; DeYoe 1988).

Pigments are photoreceptors, responsible for capturing light energy (Smith 1982). Seedling photoreceptors include: chlorophyll, phytochrome and flavins. Chlorophyll receives light energy which is converted, via photosynthesis, into chemical energy the plant can use to produce food and metabolic substrates. Phytochrome and flavins function in photomorphogenesis by initiating developmental processes (dormancy, flowering, etc.), and 'quick' action responses (stomatal opening, ion/solute balance adjustments, etc.). Pigments also mediate transfer of light signals to hormones and/or secondary messengers, which facilitate changes in cell chemistry via membrane receptors, or travel to the nucleus as messages that influence gene-related actions (Sachs and Tuan-Hua 1986; Boss and Morré 1988). Pigment destruction reduces or eliminates absorption of the light signal needed to drive these, and other, processes (Levitt 1980; Smith 1982; DeYoe 1988).

Messages arriving at the nucleus are converted by DNA into language the plant understands. These words, or phrases, arise via transcription of DNA and/or translation of messenger RNA's as special proteins called enzymes (Lehninger 1982). Loss of DNA integrity results in production of non-functional enzymes (e.g. "non-sense" words, or phrases), or no response at all (Sachs and Tuan-Hua 1986; DeYoe 1988).

Enzymes provide the vocabulary needed by the cell to interpret precisely what needs to be accomplished metabolically. Enzymes work individually, or in series, catalyzing cellular reactions that convert substrates into products. The culmination of an enzyme mediated process, which can be long and arduous, is expressed: physiologically (mobilization of food reserves, nutrient reallocation, cell membrane adjustments, etc.), or morphologically (wax deposition, leaf coloration, bud burst, lenticel development, etc.). Stress-induced enzyme damage interrupts the reaction catalyzed by the enzyme. Although a seemingly innoxious event, destruction of a single key enzyme can result in growth loss and/or death.

Why Minimize Stress to Seedlings?

Although many of the pieces of the stress puzzle await discovery, one thing is certain...stress is expensive, both biologically and economically (Bloom et.al. 1985; Chapin III et.al. 1987). The use of the seedling's resource pool for adjustment and repair limits the availability of resources for development and growth. Stress during critical transitions (dormancy induction, frost hardening or dehardening, flowering, bud flush, spring root growth, etc.) may induce delays in development (Bazzaz et.al. 1987; Bloom 1985) that increase the risk of plantation failures, and its associated costs. Healthy seedlings stay in tune with their surroundings, shifting as necessary to maintain balance, both physiologically and morphologically.

DEVELOPING A STRESS ASSESSMENT TOOL KIT

The cost to develop and implement tools that satisfactorily assess the physiological status of a seedling can be significant. However, the savings gained by avoiding plantation failures can justify the investment in stress assessment technology. Gain can be optimized by using each tool within the limits of its capabilities, as one of several tools in a "tool kit", and as part of a preventative stress management strategy that: a) identifies stressful steps in the reforestation process; b) minimizes stressful practices; c) monitors quality and consistency of operations; and d) evaluates opportunities for manipulative treatments to control developmental events or enhance stress tolerance. Using a tool kit in this manner is proactive, focusing on the problem and encouraging creativity.

Tools for Assessing Seedling Stress Response

The physiological status of a seedling has been described by a variety of terms. Most recently, seedling viability (Palta et.al. 1978), seedling quality (Duryea 1985), and stress resistance (Timmis 1980) have been used to define seedling physiological status at a given point in time. Table 2 provides a list of tools and the functional property they measure.

TABLE 2: Tests for assessing seedling physiological status.

TEST	PARAMETER	SPECIES	REFERENCE
SURVIVAL			
* Stress Test	Survival Under Stress	Douglas-fir	● McCreary & Duryea 1985
* Tissue Browning	Bud, Needle, Stem Death	Spruce & Pine	● Glerum 1985
GROWTH			
* Root Growth Capacity	Root Number/Length	Douglas-fir	● Ritchie 1985
* Bud Dormancy	Bud Set	Douglas-fir	● Lavender 1985
MEMBRANE FUNCTION			
* Electrolyte Leakage	Membrane Disruption	Spruce & Pine	● Glerum 1985
* Amino Acid Leakage	Membrane Disruption	Black Locust	Siminovitch, et.al. 1964
* Tugor Loss	Membrane Disruption	Douglas-fir	● Joly 1985
* Ethane Emission	Membrane Peroxidation	Plum	Kobayashi, et.al. 1981
* Phenol Leakage	Membrane Disruption	Douglas-fir	DeYoe & Drakeford 1987
MESOPLASMIC FUNCTION			
* ADH Activity	Enzyme Function	Poplar	Kimmerer & Stinger 1988
* Starch/Sugar	Carbohydrate Status	Douglas-fir	● Marshall 1985
* Differential Thermal Analysis	Heat of Crystalization	Pine	Burr, et.al. 1986

NOTE: Marked citations (●) in: Duryea, M.L. 1985. Evaluating Seedling Quality: Principles, procedures and predictive abilities of major tests. Workshop Proceedings, October 16-18. OSU Forest Research Laboratory, Corvallis OR.

Most tests currently being used operationally to evaluate tree seedlings fail to meet the following criteria: simple, quick and accurate. Further, few responses can be interpreted physiologically. However, by taking advantage of existing technology, increased knowledge of seedling physiology, and the power gained by aggregating tests, researchers are beginning to improve the accuracy and interpretative value of their data. The tests selected for discussion represent a sample of new approaches being developed to: a) better satisfy assessment criteria; b) link responses to known physiological reactions/processes; and c) determine the source of stress events so practices can be adjusted to minimize stress.

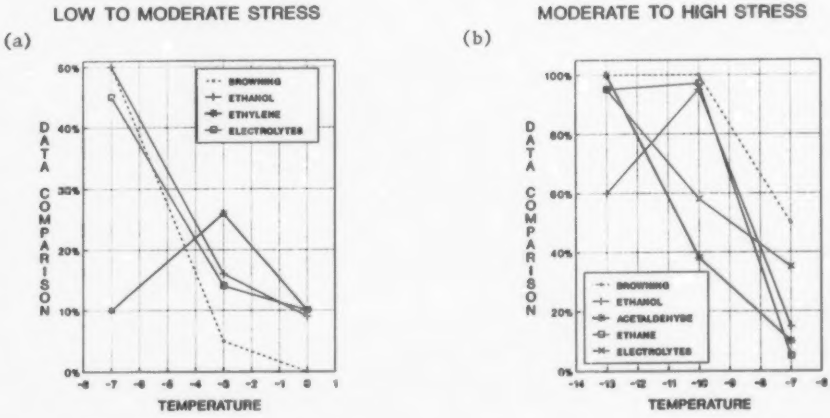
Stress-Induced Volatile Emission (SIVE)

David DeYoe (Ontario Ministry of Natural Resources, Sault Ste. Marie, Ont.), David Drakeford (Malaspina College, Nanaimo, BC), and Chris Hawkins (MacMillan Bloedel, Nanaimo, BC). Supported by FRDA Grant.

Stress-induced volatile emission (SIVE) measures 4 gases released in response to stress (DeYoe and Drakeford 1987). The gases used in developing SIVE as a tool to assess seedling physiological status include: ethylene, ethane, acetaldehyde, and ethanol (Drakeford and Hawkins 1989).

Ethylene is representative of general stress metabolism and ethane indicates breakdown of membranes by lipid peroxidation (Kobayashi et.al. 1981). Acetaldehyde and ethanol are products of anaerobic respiration (Kimmerer and Stinger 1988). DeYoe and Drakeford (1987) were able to delineate low, moderate, and severe stress of Douglas-fir seedlings subjected to operational cold hardiness testing by using visual observation of tissue (needle, bud, and stem) browning and electrolyte and phenol leakage (data not shown) to help validate SIVE response (Figure 3a and b).

FIGURE 3a and b: Comparison of SIVE analysis to tissue browning and electrolyte leakage. Availability of results: SIVE 2 days; electrolytes 4 days; browning 10 days.



LOW TO MODERATE STRESS

(a)

MODERATE TO HIGH STRESS

(b)

Low stress (-3°C) was indicated by a rise in ethylene (Figure 3a). Moderate (-7°C) stress (50% kill in browning test) induced a rise in ethanol and electrolytes as ethylene decreased (Figure 3b). Severe stress (-10 and -13°C) resulted in 100% kill. Ethanol decreased from -10 to -13°C as acetaldehyde increased, suggesting damage to alcohol dehydrogenase enzyme. Electrolytes rose steadily to -13°C, suggesting membranes were leaky, but still intact at -10°C, and disrupted at -13°C. Ethane, however, peaked at -10°C, indicating membrane peroxidation was significant enough to predict death.

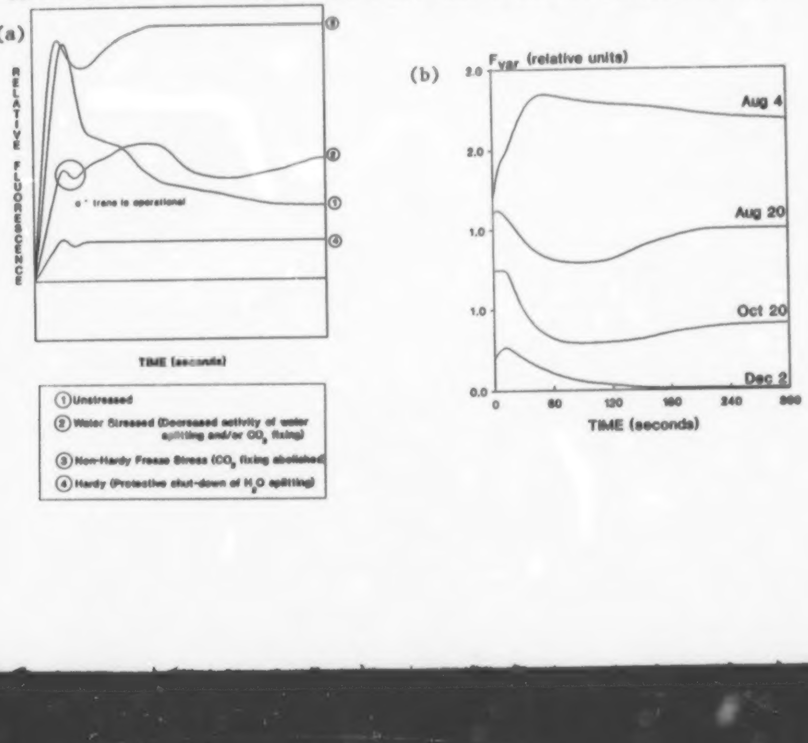
Recently, MacDonald et.al. (unpublished data) extended the practical application of the ethanol (respiratory) response to a breath alcohol analyzer, which was used to monitor ethanol production from trees subjected to air pollution in the Ohio River Valley.

Chlorophyll Fluorescence

William Vidaver, Geoff Lister and Peter Toivonen (Simon Fraser University, Vancouver, BC) and Wolfgang Binder (Ministry of Forests, Victoria, BC). Supported by FRDA and BCRC grants.

Variable chlorophyll fluorescence (Fvar) is a measure of unabsorbed light energy being photochemically dissipated from the photosystem II (Ps II) reaction centre chlorophylls. The response of photosystem photochemistry to stress is reflected in the Fvar response curve. For example, a decrease in Photosystem I (Ps I) activity, or CO_2 assimilation, results in increased Fvar, while blockage of the water-splitting reaction of Ps II causes Fvar to fall (Figure 4a and b).

FIGURE 4: (a) Typical Fvar response to stress in White Spruce (Peter Toivonen, 1987). (b) Fvar curves for White Spruce during fall/winter inactivation period. Aug. 4 (active, unstressed); Oct. 20 (uniformly low, suggesting decline in carbon fixation); Dec. 2 (no net photosynthesis).



Vidaver, et.al. (unpublished data) used Fvar response curves to assess response of White Spruce to adaptation to winter stresses (Figure 4b). The response curves are compared to survival and/or growth results in standard freeze or drought stress tests. Inferences are made regarding timing of lift, detection of freeze or desiccation damage in cold storage, and readiness to plant. Similar evaluations have been made using Scots Pine (Strand and Oquist 1988).

Biochemical Markers

Valerie Hipkins and Joe Zaerr (Oregon State Univ., Corvallis, OR)

Stress "marker" compounds were separated from methanol extracts of Douglas-fir apical shoots using high pressure liquid chromatography (HPLC) (Hipkins, unpublished data). Seedlings were exposed to cultural or stress treatments that produced a diversity of response conditions. Treatments included: freezing stress, desiccation stress, and cold storage duration, each independently super-imposed on 4 lifting dates between October and March (Treatment total = 30). Seedling response was monitored using field survival, root growth potential (RGP), a growth room stress test, and biochemical marker analysis. Although a number of statistical strategies were employed, stepwise discriminant analysis proved most effective for selecting markers. Few markers (HPLC peaks) were necessary to adequately explain treatment differences.

The authors found shared markers that demonstrate a strong relationship between RGP, field survival, and the stress test (Figure 5). Predicting field survival on an unknown lot of seedlings using markers requires selecting survival groupings, identifying the markers from a seedling sample, and subjecting marker data to discriminate analysis to classify the seedlings into appropriate survival groups. Work is currently underway to identify key markers. Once the markers are characterized, it may be possible to link predictive interpretations to the status of specific physiological reactions/processes.

FIGURE 5: The most independently informative markers of seedling survival and RGP are presented. Markers are identified by peak number and retention time (in parenthesis).

Field Survival	78 (25.19), 58 (20.48), 85 (26.28), 12 (11.18), 197 (25.04)
Growth Room Survival	78 (25.19), 133 (5.09), 35 (16.36), 125 (14.62)
Number of New Roots	78 (25.19), 133 (5.09), 89 (26.90), 12 (11.18)
Total Length of New Roots	78 (25.19), 133 (5.09), 89 (26.90), 205 (27.02)

Methanol extracts of Douglas-fir apical shoot extracts were separated by HPLC. Column: C-18 reverse phase. Mobile phase: methanol in 20mM triethylamine acetate buffer, pH 3.37. Flow rate: 1 ml/min. Gradient: forty minute, four step solvent program. Detectors: (A) UV absorbance at 254 nm, detected peaks 1 to 128, (B) fluorescence intensity at emission and excitation wavelengths of 360nm and 290nm, respectively. Peaks 129 to 230 were detected.

SUMMARY

Stress to a seedling is a function of imbalances and/or extremes in temperature, light, moisture, atmosphere, nutrition, and physical/chemical factors. Stress events are cumulative, each event causing the seedling or tree to shift metabolism from development and growth toward adjustment and repair. Seedling stress response and recovery time depend on duration, intensity, timing and frequency of stress events. If our perception of stress is not in tune with that of the seedling, then stresses we 'unwittingly' impose on trees during seedling production, handling and planting, or plantation and stand tending, will limit productivity. These risks can be minimized by developing stress assessment "tools" that elucidate seedling physiological status. To be practical, these tools must be simple to use, quick, and accurate. To minimize decision risk, the measured response should be definitive and linked to a known physiological process or reaction. To be of optimal interpretive value, a "tool kit" approach should be used to develop a more composite picture, and to help ensure that each tool is used within the limits of its capabilities.

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LIGHT ABSORPTION AND WILLOW PRODUCTION IN SOUTHERN SWEDEN, A CASE STUDY

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FDC: 161.32: 231.4: 537: 176.1 Salix viminalis L.

SUMMARY

The quantum use efficiency (ε) was determined during three growing seasons for a short rotation forest in southern Sweden. The stem and leaf production, the leaf area index and the incident light quanta above and below the canopy were measured. The stand was irrigated and fertilized in order to maximize the yield. The aim of the study was to examine the seasonal values of ε for a coppicing Salix viminalis stand growing under optimal water and nutrient conditions. The seasonal values for ε_s (stem growth) in 1986, 1987 and 1988 was 0.28, 0.44 and 0.32 g E^{-1}, respectively while the corresponding ε_{sh}-values (shoot growth) equaled 0.36, 0.54 and 0.42 g E^{-1}. ε_s and ε_{sh} for all three seasons was 0.34 and 0.43 g E^{-1}, respectively. The stem production corresponded to an energy conversion efficiency of incoming shortwave radiation of 1.2%. The higher ε-values of 1987 were related to a colder and more humid climate than for the other years. This study indicates that ε_s and ε_{sh} vary as a function of weather and/or shoot age.

Keywords: Quantum use efficiency, coppicing

INTRODUCTION

Plant growth is known to depend on several environmental and internal factors. Nevertheless, attempts are often made to examine the effect of single factors by assuming proportionality between the factor concerned and the growth. Depending on which factor is studied or assumed to be the most limiting, growth is taken as proportional to, for instance, transpiration, plant nitrogen status or temperature. Another approach, the one followed in this paper, is to assume that growth is proportional to the radiation absorbed by the leaves (Monteith 1977 and Gallagher &

Biscoe 1978 for crops; Jarvis & Leverenz 1983 and Linder 1985 for evergreen tree species; Cannell et al. 1987, 1988 for willow and poplar). This relationship is named the quantum use efficiency (ε) in this paper. Often the idea is to relate the total growth to the amount of light quanta (I) absorbed by the leaves following the idea that the amount of CO_2 molecules taken up is proportional to the number of light quanta absorbed. In this study we try to make this test. However, for practical reasons we have replaced the total growth with shoot (stem plus leaf) growth and the light absorbed by the leaves with that absorbed by the whole shoots. The influence of root production on the variations in ε was kept at a minimum by cultivation on a sandy soil and by application of intense irrigation and fertilization.

The willow stand investigated was part of the Långa-Veka project and the aim of the trials was to achieve maximal yields for different clones of _Salix_ (Christersson 1987). For one of the stands we measured the light absorption and biomass production in order to determine the seasonal values of ε for a stand growing under natural conditions but with optimal water and nutrient supply. For within season variations and a more detailed description of the experiment is referred to Eckersten & Nilsson (1990).

EXPERIMENTAL METHODS

Quantum Use Efficiency

The quantum use efficiency (ε) was defined as the biomass production (ΔW) per unit of light (400 - 700 nm) quanta absorbed by the shoots (I_a).

$$\varepsilon = \Delta W/I_a \qquad (1)$$

where ΔW is either the total shoot growth (leaves + stem) or only the stem growth, then giving ε_{sh} and ε_s respectively. The absorbed light (I_a) equals the incident light above the canopy (I_h) minus the amount reflected at this level (I_{hr}) and the amount penetrating to the soil surface (I_g). We have:

$$I_a = I_h(1 - \alpha - q) \qquad (2)$$

where α is the coefficient of reflection (equal to I_{hr}/I_h) and q is the fractional penetration of I_h (equal to I_g/I_h).

Site Description

The experimental area at Långa-Veka (Lat. 57 ^{O}N, alt. 5-10 m) is located on the western coast of Sweden (about 100 km south of Göteborg) close to a small river and 1 km inland from the coast of Kattegat. The experimental site was on abandoned farmland with a sandy soil. The stand was planted in 1982 with Salix viminalis, clone 081, on a 40 m by 50 m area, with a spacing of 70 cm by 40 cm and surrounded by similar stands. The plantation was fertilized and irrigated by a drip irrigation system on a weekly basis (see further Christersson 1986, 1987). The stand was harvested in the winter of 1985-86, then giving first season coppice shoots in 1986, second season coppice shoots in 1987 and third season coppice shoots in 1988. The leaf nitrogen concentration of the fully developed top-leaves was measured at least once a month (Lars Christersson, unpublished data). The weather data was taken from the closest network station. The recorded relative air humidity at 1 p.m. was selected to represent daytime conditions.

Biomass Measurements

A part of the site was chosen for making studies on quantum use efficiency. This subplot was chosen to have a maximal homogeneity in biomass and consequently a minimal variability in absorbed light. Also, the subplot was representative of the whole stand in terms of growth and development of leaf area. Here, the performance of the stand early in 1986 was used as a selection criteria. Within the subplot where I_g was measured, 28 plants were selected for representing the growth of this area. Those 28 plants were utilized over the whole 3-year period for estimating biomass and leaf area of the subplot. Simultaneously with estimates of biomass of the subplot, biomass of the whole stand was measured by use of a number of other plants systematically distributed over the whole stand. For this purpose 54 plants were utilized during 1986 and 109 plants during 1987 and 1988. These measurements thus enabled a check to be made of how representative the 28-plant sample data were for the performance of the whole stand.

Biomass of stems and leaves and leaf area of the growing plants were estimated by use of allometric relationships between stem diameter and/or stem height in combination with measurements of the same variables of individual shoots of the growing stand (Whittaker & Marks 1975; Nilsson 1985; Nilsson & Wasielewski 1987). The allometric relationships were determined using data on dry weight of foliage and stems, leaf area, stem diameter and height during different occasions during the growing season. Shoots of all sizes belonging to a particular plant were utilized unless their sizes were insignificant. Biomass data were converted into tonnes of dry weight per hectare (W_s and W_l) and leaf area index (A_{li}) by use of the planting density (see further Eckersten & Nilsson 1990).

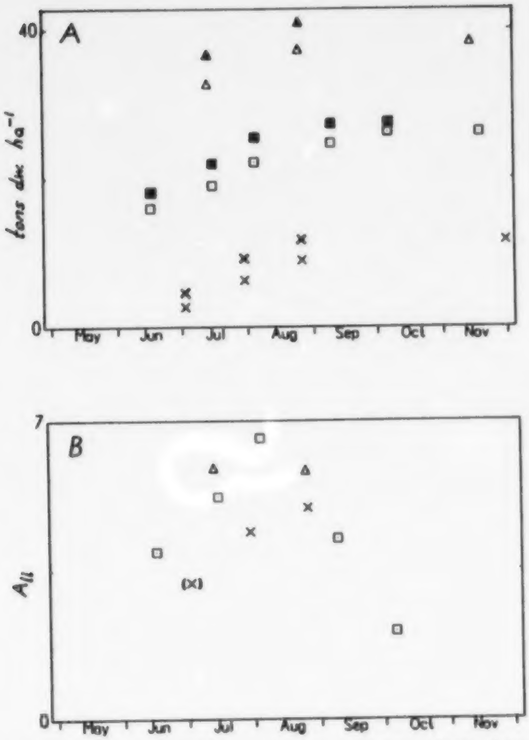
Light Measurements

The photosynthetic active radiation incident on a horizontal surface (I; 400-700 nm) was measured for three consecutive growing seasons, above and within the willow stand. The measurements were performed between June 15 and November 15 in 1986, May 18 and November 29 in 1987 and between April 8 and December 19 in 1988. One quantum sensor (LI-190s, LI-COR) was placed above the stand at a level of 600 cm, measuring I_h. A tube quantum sensor (Line quantum, LI-COR), which integrated the light over a 1-meter long array, was placed at 30 cm level measuring the light reaching the soil surface (I_g). During the period from May 5 to June 12 in 1988 the light quanta reflected by the canopy (I_{hr}) was measured at the same location as for I_h and with the same type of sensor. The daily sums of I_h, I_g and I_{hr} were recorded by integrators (LI-510B/011M/20, LI-COR).

In order to estimate the amount of light absorbed by the shoots (I_a) during the whole season it was necessary for some periods to substitute missing values in the database. The corrections introduced was related to problems in the measurements of I_g from July to October in 1988, lack of light measurements in the beginning of the growing seasons of 1986 and 1987 and to the absorption of light by leaves below the 30 cm level in the beginning of 1986. (see further Eckersten & Nilsson 1990).

RESULTS

The annual stem production of the subplot was 11.7 tonnes d.w. ha^{-1} in 1986. It increased in 1987 by 25% and then decreased in 1988 by 17% (Table 1). The seasonal maximum of the leaf area index behaved in a similar way. In 1986 it became 5.0, in 1987 it was 6.6 and in 1988 it was at least 5.9 (Fig. 1b). Over the 3-year experimental period, growth at the subplot where I_g was measured, deviated only slightly (< 3%) from the growth of the whole stand. Total stem biomass of the whole stand was determined at the end of 1988 after harvesting using a fresh weight and water content estimation technique (Lars Christersson, pers. comm. 1988). The value for the 3-year production deviated only 1.5% from our corresponding estimate.



Figures 1a and b: (a) Standing shoot (stem plus leaf) biomass (filled symbols) and stem biomass (open symbols). (b) Leaf area index (A_{li}). Salix viminalis, Långa-Veka. x = 1986; □ = 1987 and △ = 1988. () represents an estimated value.

The light reflection coefficient (α) was determined as a mean during a 39-day period to be 0.037 (rel. st. dev.= 8%, n=39). The earlier canopy closure of the older shoots made the fractional penetration of light (q) decrease faster. Also the seasonal initials decreased with shoot age (Fig. 2). In 1987 the leaf shedding started already in the middle of August (see also Fig. 1b) with a corresponding increase in q, which is about a month earlier than in 1986 and 1988. The growing periods were estimated to start on May 15 in 1986 and May 1 in 1987 and 1988 and assumed to stop on November 15.

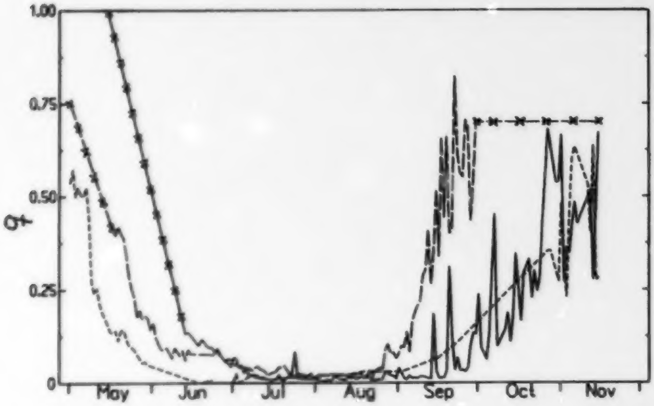


Figure 2: The fractional penetration of light through the canopy (q) expressed as the ratio between daily sums of light quanta), in a *Salix viminalis* stand at Långa-Veka. Lines with crosses represent extrapolations of the measurements. Lines are: ——— = 1986, — — = 1987 and - - - = 1988.

Table 1: Seasonal values for *Salix viminalis* at Långa-Veka of quantum use efficiency (ε_{sh} = shoot, ε_s = stem; g E^{-1}) and the corresponding values of maximum stem biomass and leaf biomass (W_{smax} and W_{lmax}; tonnes ha^{-1}), light absorbed by the canopy and incident above the canopy (I_a and I_h; E m^{-2}), air temperature (T_a; °C), relative air humidity at 1 p.m. (H_a; %), top-leaf nitrogen concentration (n_l; %) and leaf biomass to leaf area ratio (b_A; g m^{-2}). ε'-values are functions of I_h.

Season	ε_{sh}	ε_s	W_{smax}	W_{lmax}	ε_{sh}'	ε_s'
1986	0.36	0.28	11.7	2.9	0.29	0.23
1987	0.54	0.44	14.6	3.3	0.40	0.33
1988	0.42	0.32	12.2	3.9	0.37	0.32

Season	I_a	I_h	T_a	H_a	n_l	b_A
1986	4088	5101	12.1	52	3.8	62
1987	3304	4483	11.2	66	4.0	58
1988	3811	4321	12.9	56	3.7	65

In 1987 ε_{sh} was higher than for the other two years. Since the leaf fall had to be estimated ε_{sh} was more difficult to determine than ε_s. However, ε_{sh} was achieved by assuming that the total seasonal shoot growth is the sum of the maximum stem biomass and the maximum leaf biomass during the season. Then ε_{sh} of 1987 was 29% higher than in 1988 and 50% higher than in 1986 (Table 1). For all three growing periods ε_{sh} was 0.43 g E^{-1}.

If ε was based on the light received by the stand (which was almost proportional to the incident total radiative energy) instead of the light absorbed the variation between years decreased (i.e. I_a is substituted with I_h in Eq. 2 then giving ε' instead of ε; see Table 1).

The quantum use efficiency defined for the stem production (ε_s; see Eq. 2) behaved fairly similar to ε_{sh}, except that it varied slightly more (Table 1). For all three growing periods ε_s was 0.34 g E^{-1}. The quantum use efficiency defined for stem production and incident light quanta (ε_s') varied also more than the corresponding values for the shoots (Table 1).

DISCUSSION AND CONCLUSIONS

The accuracy of the biomass measurements is better than 10% for shoot production and 5% for stem production. The corresponding figure for the light measurements is 5%, indicating that the maximal error in ε_{sh} and ε_s is probably considerably smaller than 30 and 20%, respectively. In addition to this we also have four other uncertainties related to (i) the increased variation in q from the middle of September (Fig. 2), (ii) the I_a estimates of the first period in 1986 (May 15 - July 2) and two periods in 1987 (May 1 - May 17 and October 1 - November 15; Fig. 2), (iii) the assumption that the measured q represents the average q of the whole subplot and (iv) the difficulty to determine ε_{sh} since the leaf fall was not measured. The effects of (i), (iii) and (iv) are estimated to have been small but including (ii) the maximal error limits in ε_{sh} and ε_s are increased in 1986 and 1987 by 5-10 percentage points (see further Eckersten & Nilsson 1990).

In order to examine to what extent the variations in ε_{sh} reflect the variations in the quantum use efficiency defined on the basis of total production (ε_t) the assimilates translocated to the roots and from the roots must be included. We assume that root production can account for 10-15% of the variations in ε_t. The fraction of measured growth that originates from assimilates stored in the roots during the previous years was perhaps slightly higher in 1986 than in the other years (because of recently harvested shoots). Hence the variations in ε_{sh} are not enough high to show if there have been any variations in ε_t.

In some studies ε is based on radiation defined as the energy of the absorbed light (400 - 700 nm) (cf. Gallagher & Biscoe 1978). A rough comparison for clear sky conditions between that type of ε-values and those presented here could be made by multiplying our values by 4.55 E MJ^{-1} (cf. Tooming & Gulyaev 1967). In other studies radiation is defined as the total shortwave radiation (300 - 3000 nm). The concept is then that growth is proportional to the total amount of absorbed energy rather than to the number of absorbed light quanta. By multiplying our ε-values by 3.4 E MJ^{-1} they could be compared with those of, for instance, Cannell et al. (1987) who estimated ε_{sh} defined in this way for S. viminalis growing in Scotland. The corresponding seasonal ε_{sh}-values at Långa-Veka ranged between 1.2 and 1.8 g MJ^{-1}. For all three growing periods ε_{sh} was 1.5 g MJ^{-1}. These values are up to 30% higher than those reported by Cannell et al. (1987). Our ε-values are also high in comparison with those for crops and other tree species reported in reviews by Cannell et al. (1987) and Cannell (1989). Only field beans in England had a higher value (ε_{sh}=2.1 g MJ^{-1}, Fasheun & Dennet 1982).

In energy forestry it is convenient to express the quantum use efficiency in terms of energy conversion efficiency of the incoming shortwave solar energy (R_h). Assuming that the energy content per gram of dry matter was 19 kJ (cf. Cannell et al. 1988) the ε'-values of Table 1 (multiplied by 0.044 E g^{-1}) correspond to 1.0 - 1.4% of seasonal R_h, being converted into stem biomass and 1.3 - 1.7% into shoot biomass.

The variations in ε between years are close to the limits of the estimated minimum accuracy, however the increase of ε_s and ε_{sh} during 1987 are outside these limits and should be regarded as an effect of variation in weather and/or shoot age. On an annual basis ε_s is often used to determine the production as a function of the absorbed light. In this study, the annual stem production of a stand at close to maximum shoot growth rate, varied between 85% and 125% of the production determined using the ε_s-value of all three seasons.

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MESURES BIOPHYSIQUES DE LA VIGUEUR DES ARBRES

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SUMMARY

In relation with the forest decline phenomenon, three biophysical tests have been considered.

The aim of this study is to obtain a good estimation of the vitality of the tree for an early diagnostic of the dieback.

The three biophysical tests considered are :

- the electrical resistance of the cambium which has been particularly studied
- the electrical capacitance of the cambium
- the oscilloscope technique

The advantages and the disadvantages of these three methods to asses tree vigor are given.

Keywords : Biophysical tests, tree vitality, electrical resistance of the cambium, electrical capacitance of the cambium, oscilloscope technique.

INTRODUCTION

Tout au long de leur vie, les arbres sont soumis à de nombreux agresseurs biotiques et abiotiques qui affectent leur vitalité.

Afin d'obtenir le plus rapidement possible une idée sur la présence d'un de ces agresseurs et sur l'étendue des zones forestières touchées, pour pouvoir mettre en oeuvre le plus tôt possible les moyens de lutte contre ceux-ci, il a été mis au point et développé un certain nombre de tests pour le diagnostic précoce.

Nous pouvons définir un "test" comme une méthode simple permettant d'évaluer des modifications caractéristiques au niveau d'un "paramètre physiologique" de l'arbre et ceci le plus rapidement possible avant que des symptômes visibles n'apparaissent. De plus afin de pouvoir caractériser les agresseurs, ces tests doivent être dans la mesure du possible, spécifique de ceux-ci.

Les paramètres physiologiques susceptibles de se modifier avec la vitalité de l'arbre sont innombrables, mais dans la pratique, seul un nombre réduit de ceux-ci sont utilisés comme tests.

Généralement, les paramètres choisis sont ceux qui permettent d'obtenir rapidement de nombreux résultats avec un minimum de manipulation et en utilisant une méthode ou un appareillage simple.

Les tests pouvant être mis en oeuvre peuvent se diviser en trois grandes catégories : les tests morphologiques qui font intervenir des changements d'ensemble sur certains organes de l'arbre, des tests physiologiques qui concernent plus particulièrement des processus physiologiques à l'échelle des tissus et des tests biochimiques qui peuvent aller jusqu'à l'étude des systèmes enzymatiques au niveau cellulaire.

A l'intérieur de chacune de ces catégories, les tests se divisent en trois domaines selon la partie de l'arbre considérée : tests foliaires, tests corticaux et tests racinaires.

Avec l'apparition du phénomène du dépérissement des forêts, il est de plus en plus demandé une évaluation rapide sur le terrain de la vigueur des arbres. L'appréciation visuelle de la perte de feuilles ou d'aiguilles des arbres a été le test physiologique le plus utilisé jusqu'à présent pour l'estimation et l'inventaire des dégâts aux forêts entraînés par ce phénomène. Toutefois cette méthode d'évaluation par observation comporte une part de subjectivité avec également une fiabilité et une précision toute relative.

Pour conserver les avantages de la rapidité et de l'utilisation directe sur le terrain, il a été développé des "test biophysiques" comme la mesure de la résistance électrique du cambium qui donne une évaluation quasi instantanée et non destructive de la vitalité de l'arbre. Ce test a surtout été utilisé avec succés dans le passé pour caractériser une grande perturbation de la forêt : les attaques d'insectes.

Au niveau du tronc, outre la mesure de la résistance électrique du cambium, deux autres tests biophysiques voisins sont à signaler : la mesure de la capacitance électrique du cambium et la technique par oscilloscope.

MESURE DE LA RESISTANCE ELECTRIQUE DU CAMBIUM

De très nombreux travaux ont été consacrés aux relations aui existent entre la vigueur des arbres soumis à des stress biotiques ou abiotiques et la mesure de la résistance électrique du cambium (Wargo et Skutt 1975 ; Shortle et Ostrofsky 1983 ; Tomiczek 1987).

Cette mesure nécessite l'implantation de deux électrodes au travers de l'écorce dans la zone cambiale vasculaire (cette zone comprend le cambium, mais également les parties conductrices du phloème et du xylème de part et d'autre du cambium). La résistance électrique de cette zone dépend essentiellement de la présence d'ions mobiles, principalement du potassium présent dans l'apoplaste situé entre les deux électrodes (Malia et Tattar

1978 ; Blanchard *et al.* 1983). Cette résistance électrique est inversement proportionnelle à la vitalité de l'arbre : quand la résistance électrique augmente, la vitalité de l'arbre diminue.

Cependant de nombreux paramètres physiologiques internes ou environnementaux externes à l'arbre peuvent modifier les résultats (Newbanks et Tattar 1977 ; Piene *et al.* 1984).

La mesure dans le tronc de la résistance électrique des tissus ligneux au niveau du cambium est effectué au moyen d'un appareil baptisé "vitalomètre".

Cet appareil a été mis au point à l'initiative du cabinet R. de Legge (12, rue d'Aguesseau, 92100 Boulogne, France) et est basé sur le même principe que le "shigomètre" américain (Skutt *et al.* 1972).

Le "vitalomètre", comme son homologue américain comprend deux parties reliées entre elles par un cable électrique :

- une sonde de mesure, à enfoncer dans le tronc, constituée de deux électrodes conductrices sous forme de deux fortes aiguilles d'acier de 4,2 cm de long séparées de 1,8 cm. Ces aiguilles sont insérées à leur base dans un bloc de plastique comportant une poignée.
- un boitier portable alimenté par batterie délivrant un courant pulsé de forme carrée (de façon à éviter les phénomène de polarisation dans le bois). La résistance des tissus au courant entre les électrodes est lue sur un écran à affichage digital (valeur comprises entre 0 et 200 kohm).

Depuis les années 1970 un phénomène de dépérissement forestier est apparu dans un certain nombre de forêts européennes et françaises. Dans ces forêts, ce dépérissement se caractérise en particulier au niveau des épicéas par des jaunissements, mais surtout par des chutes d'aiguilles plus ou moins importantes (Schutt et Cowling 1985, Garrec 1986).

Dans le cas de défoliation plus ou moins importantes suite à des attaques d'insectes, la mesure de la résistance électrique du cambium a été largement utilisée par les pathologistes forestiers et a montré ses possibilités pour estimer l'état physiologique des arbres (Davis *et al.* 1980 ; Gagnon *et al.* 1987 ; Mac Dougall *et al.* 1987).

A partir de ces résultats , il nous est paru intéressant d'étudier les possibilités de ce test pour estimer la vigueur des arbres dépérissants qui se caractérise par des chutes d'aiguilles.

L'étude de la résistance électrique du cambium a montré que dans les troncs d'épicéas, celle-ci augmente avec le niveau de dépérissement des arbres (cf figure 1). Dans cette étude éffectuée en fonction du diamètre des arbres, nous mettons en évidence que la résistance électrique diminue lorsque le diamètre de l'arbre augmente (Garrec *et al.* 1989).

Il apparait ainsi que le diamètre des arbres (fonction de l'âge, du statut social etc...) est une facteur très important qui, dans les arbres dépérissants se répercute sur la réponse de ceux-ci au niveau de la résistance électrique du cambium. On constate en effet que les variations de cette résistance entre les différentes classes de dépérissement, sont nettement plus significatives dans les arbres de petits diamètres comparativement aux arbres de diamètres supérieurs.

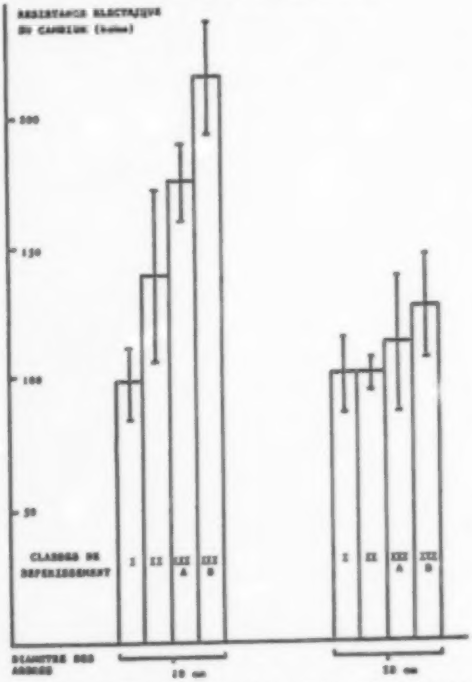


Figure 1 : Influence du "dépérissement" des épicéas sur la mesure de la résistance électrique du cambium pour différentes catégories de diamètres.

Lorsque l'on étudie cette résistance dans des épicéas de différentes régions, on constate que l'on obtient des valeurs différentes de la résistance électrique moyenne selon les régions et ceci pour une même gamme de diamètre et un même niveau de dépérissement. Ceci indiquerait que l'influence du diamètre sur la résistance est différente selon les stations (cf figure 2). En général, les arbres des stations sur sol pauvre ont comparativement à ceux des autres stations, des résistances électriques plus élevées.

Ces résultats que nous interprêtons comme une indication sur l'indice de fertilité des stations, montrent qu'il est impossible, sans précautions, de comparer entre elles les mesures de la résistance électrique du cambium d'une forêt à une autre.

De même on constate une brusque augmentation, dans la plupart des cas, de la résistance électrique dans les arbres de diamètre inférieur à 10 cm. Nous pensons que cettte augmentation des valeurs de la résistance provient du fait que nous avons alors à faire à des arbres ayant une forte proportion de bois juvénile (arbres agés de moins de 20 ans) de faible densité et de faible texture. Il ne semble donc pas possible de comparer les valeurs obtenues avec les bois juvéniles à celles obtenues avec les bois adultes.

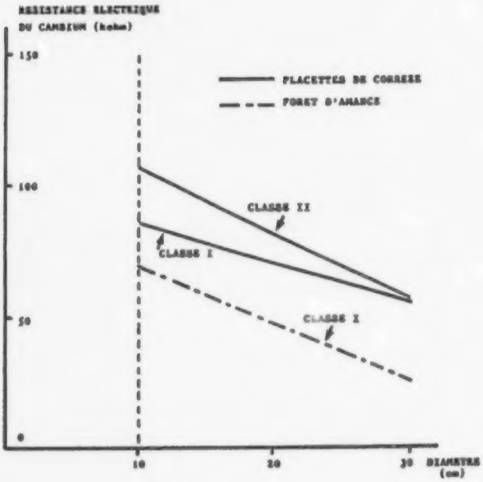


Figure 2 : Evolution de la résistance électrique du cambium en fonction du diamètre suivant les classes de dépérissement et l'emplacement des stations.

- Placettes de Corrèze : sol pauvre
- Forêt d'Amance : sol riche

Parallèlement de nombreux facteurs internes ou externes à l'arbre modifient les valeurs de la résistance électrique du cambium. Parmi ceux-ci, nous pouvons citer : l'insertion des electrodes (profondeur d'enfoncement, hauteur sur le tronc, position sur la circonférence, durée de la mesure), statut social et âge de l'arbre et des facteurs liés au cycle végétatif, au cycle journalier et aux paramètres climatiques.

Malgrè ces restrictions, il apparait que la mesure électrique du cambium est correlée avec l'état sanitaire des épicéas (dépérissement). Cette mesure donne avant tout une indication de la vigueur globale de l'arbre (état physiologique). Cette vigueur est fonction de l'état apparent de l'arbre (chute d'aiguilles, statut social, etc...), mais elle intègre vraisemblablement d'autres facteurs comme des modifications physiologiques et métaboliques non visibles. D'une certaine façon cette mesure ponctuelle pourrait nous renseigner sur l'état à venir de l'arbre.

Si cette méthode peut présenter un grand intérêt au niveau d'un peuplement, par contre, son utilisation systématique en symptomatologie pour indiquer rapidement sur une vaste étendue la vigueur relative des arbres reste problématique. En effet, il apparait que la résistance est aussi fonction des conditions stationnelles.

Toutefois, de part la rapidité, la simplicité et la relative précision des mesures, cette méthode semble particulièrement prometteuse pour suivre dans le temps, en complément d'autre méthodes (appréciation visuelle des houppiers, mesure de la croissance), la vitalité d'arbres ou de parcelles.

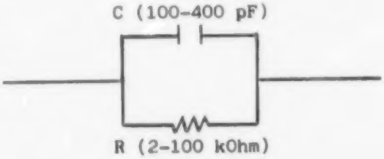
MESURE DE LA CAPACITANCE ELECTRIQUE DU CAMBIUM

Si la mesure de la résistance électrique du cambium est facile à obtenir, par contre l'interprétation des résultats demande certaines précautions car des facteurs comme la période de la journée, les conditions environnementales (température en particulier) aussi bien que la période de l'année ont une forte influence sur ceux-ci.

La mesure de la capacitance électrique du cambium est une alternative possible. Cette mesure est reliée en partie à la concentration en ions de l'apoplaste, mais elle dépend surtout de la polarisation des surfaces membranaires, paramètre qui est peu affecté par les variations journalières de la température.

La mesure de la capacité electrique du cambium s'effectue avec les mêmes electrodes que celles utilisées pour les mesures de la résistance.

Sur le schéma ci-dessous nous avons représenté le modèle electrique simplifié des tissus végétaux (Paszewski *et al.* 1982) :



A partir de ce modèle, nous constatons que l'impédance du circuit à une fréquence inférieure à 100 Hz est égale à la résistance R du circuit. Par contre, pour une fréquence supérieure à 50 kHz, l'impédance du circuit dépend autant de la capacitance que de la résistance.

Dans la réalité, une première mesure à 27 Hz est effectuée et donne une valeur de la résistance, tandis qu'une deuxième mesure à 87 kHz renseigne sur l'impédance du circuit et permet alors de calculer la capacitance connaissant la résistance (Mac Dougall *et al.* 1987 ; Mac Dougall *et al.* 1988).

Si la résistance électrique du cambium augmente lorsque la vigueur de l'arbre diminue, par contre la capacitance électrique du cambium diminue lorsque la vitalité de l'arbre diminue (Piene *et al.* 1984).

A partir des différents travaux qui ont été effectués pour comparer entre elles la mesure de la résistance et la mesure de la capacitance électrique du cambium pour la détermination de la vigueur des arbres, il semble que la mesure de la capacitance est mieux correlée à la vitalité des arbres.

Les mesures de la capacitance qui sont surtout reliées aux caractéristiques des membranes cellulaires seraient plus stables que les mesures de la résistance reliées aux contenus en eau et en ions des tissus. Les membranes sont internes aux cellules et seraient de ce fait moins sujettes aux changements de l'environnement. De plus les membranes, parties vivantes et fonctionnelles des cellules reflèteraient d'une façon plus précice l'"état de santé" des cellules.

Les mesures de la résistance qui dépendent surtout des ions seraient avant tout représentatives des potentiels hydriques et des stress hydriques, mais les concentrations en ions sont aussi un bon reflet de l'activité métabolique des tissus et donc un bon indicateur de la "vitalité". (Mac Dougall *et al.* 1987)

Cette relative insensibilité aux conditions environnementales fera donc préférer la méthode de la mesure de la capacitance electrique électrique du cambium lorsque l'on veut estimer la vigueur d'un très grand nombre d'arbres ou de parcelles lors d'expériences s'étalant sur un grand laps de temps.

LA TECHNIQUE PAR OSCILLOSCOPE

Dans cette méthode, un générateur de signal carré (1000 Hz) envoie une onde vers deux électrodes (espacées de 7 mm) fichées dans les tissus du tronc de l'arbre. Cette onde est plus ou moins déformée quant elle traverse les tissus végétaux, et cette variation récupérée par deux autres électrodes situées à proximité immédiate des précédentes et espacées de 7 mm, apparait sur l'écran d'un oscilloscope.

Sur la figure 3 ci-dessous, nous avons représenté les différents signaux déformés qui peuvent apparaitre sur l'oscilloscope. Le signal 1 correspond à un tissu végétal actif (en croissance), le signal 2 à un tissu en phase de dormance et le signal 3 à un tissu mort (Ferguson *et al.* 1975).

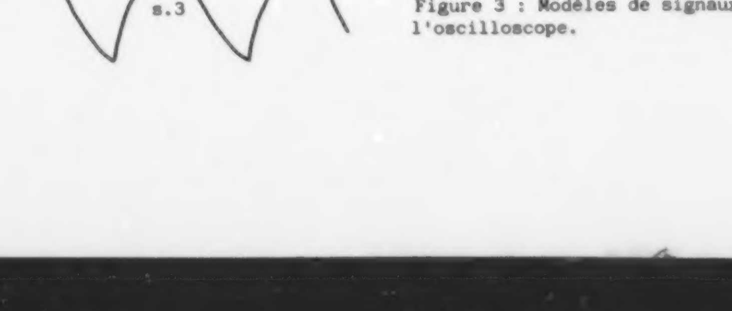
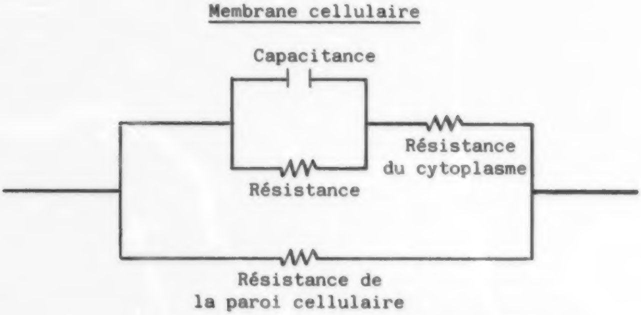


Figure 3 : Modèles de signaux sur l'oscilloscope.

Pour expliquer cette réponse à l'activité physiologique des arbres, la section des tissus entre les électrodes est représentée comme précédemment par un circuit électrique comprenant des résistances et des capacitances reliées en parallèle et en série.

Sur le schéma ci-dessous, nous avons représenté le modèle électrique équivalent aux tissus végétaux (Hayden *et al.* 1969).



On admet généralement que les changements dans l'état physiologique des arbres se reflètent avant tout dans la valeur de la capacitance de la membrane cellulaire. Quant l'arbre est très actif, cette capacitance serait particulièrement élevée ce qui entrainerait la forme du signal 1. Quant l'arbre se met en dormance, la valeur de cette capacitance diminue et l'on obtient la forme du signal 2. Dans un arbre dépérissant ou mort, la capacitance des membranes cellulaires devient très faible et l'on obtient la forme du signal 3 (Ferguson *et al.* 1975).

On ne connait pas exactement quels changements dans la membrane cellulaire entrainent des variations de sa capacitance, mais on pense qu'elles peuvent provenir de modifications de son épaisseur ou de sa perméabilité.

Cette technique a été particulièrement développée pour détecter la mise en dormance des arbres (Ferguson *et al.* 1975 ; Holbo *et al.* 1981), mais elle a également été utilisée pour déceler l'existence de tissus végétaux plus ou moins morts avant l'apparition de symptômes visuels (Zaerr 1972). Elle permet également de déterminer l'état hydrique d'un arbre (Grieu 1986).

CONCLUSION

A partir des 3 tests biophysiques pour estimer la vigueur des arbres que nous venons de passer en revue, nous pouvons donc tirer les conclusions suivantes :

- La mesure de la résistance électrique du cambium est la méthode la plus utilisée, la plus facile à mettre en oeuvre, mais elle dépend assez fortement des conditions environnementales.

- La mesure de la capacitance électrique du cambium est la méthode la mieux corrélée avec la vigueur des arbres, elle est peu sensible aux conditions environnementales, mais elle est plus difficile à mettre en oeuvre.

- La technique par oscilloscope est une méthode prometteuse mais qui n'a pas beaucoup été développée jusqu'à présent, et elle est assez difficile à mettre en oeuvre.

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THE PHYTOGRAM TECHNIQUE

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SUMMARY

The PHYTOGRAM technique consists of the measurement of extracellular electropotentials from invasive electrochemical, sensors placed in the stem or lateral branches of the tree. The object of this investigation was to test the ability of the technique to discern differences between anthropogenically impacted and healthy Douglas Fir at two sites on Vancouver Island. Measurements made every fifteen minutes from August of 1988 to August of 1989 yielded very significant differences in the PG11 and PG12 indices between the two sites. Under the oxygen and peroxide hypotheses, these indices are interpreted in terms of quantitative scales of respiratory activity and autotoxicity, respectively.

Keywords: PHYTOGRAM, electrochemical, potential

INTRODUCTION

The PHYTOGRAM technique consists of the insertion of an electrochemical sensor in the main stem or lateral branch of the tree. A reference electrode is placed in the soil. The two electrodes yield an electropotential which varies with the status of the tree and changes in the environment (Gensler, 1980, 1986, 1988).

There are three ranges or zones of potential (Gensler, 1989). The normal range is from 300 to 700 millivolts relative to the standard hydrogen electrode. The potential exhibits a diurnal periodicity consisting of a rise in the morning hours to an afternoon plateau, then a decline in the late afternoon and early evening. This decline in potential ensues until dawn at which time the potential rises once again.

The second or hypo-potential range extends from about zero to 300 millivolts. This range is entered when the plant is subjected to very wet conditions. Residence in this range is usually transitory, but under sustained wet soil, the potential will remain at these low levels.

The third or hyper-potential range is characterized by very high potentials, from 700 up to 1400 millivolts. Movement into and out of this range is very rapid and has given rise to the term "spiking." This range is entered only under a relatively specific combination of temperature and light. The potential rise occurs in the mid or late morning and the potential fall occurs in the afternoon.

The potential characteristics in each zone have been related to environmental changes on a purely empirical basis without recourse to a knowledge of the underlying electrochemical reactants. Empirical observations and in vitro experiments have given rise to the "Oxygen Hypothesis"(Gensler, 1988a). Under this hypothesis, the potential is a measure of the oxygen concentration in the extracellular fluid. An increase in oxygen consumption in the mitochondria within the cell causes a movement of oxygen into the cell and a subsequent decrease of oxygen in the extracellular region. This causes a decrease in measured potential. Conversely, an increase in the potential is an indication of an increase in the oxygen concentration. The observed diurnal periodicity in potential is a manifestation of an oxygen replenishment/usage cycle.

The hypothetical dominant reactant in the hypo-potential zone is the ethanol-acetaldehyde couple. Here the plant shifts into a respiration mode dominated by this reaction. Empirically, one observes entry and subsequent residence in this zone under very wet soil conditions.

While movement within the normal and anaerobic zones can extended over indefinite periods, residence in the hyper-potential zone is almost always a daytime phenomenon and only occurs under the specific conditions of relatively low predawn and early morning temperatures concomitant with a high light level. This empirical observation plus the very high measured values in the scale of biological reactants has led to the hypothesis that the causative reactant is hydrogen peroxide. The proposed mechanism is as follows: under sunny conditions, the photosynthesis reaction produces a stream of electrons. This stream is normally consumed by the NADP-NADPH reaction. But under low temperature, this energy sinking reaction is inhibited. The electron stream is channeled into the formation of super oxide radicals which are immediately converted into peroxide. This peroxide diffuses out of the cell and is measured by the electrode.

OBJECTIVE

The objective is to test two PHYTOGRAM indices: 1) an index of "respiratory activity" based on potential excursions in the normal and near anearobic zones, 2) an "autotoxicity" index based on excursions in the hyper-potential zone.

EXPERIMENTAL METHODS

This paper will report on the results from two sites on Vancouver Island: the Port Alice site three kilometers east of the Port Alice mill and the Alice Lake site on the east central shore of Alice Lake (Table 1).

Table 1: Characteristics of the Port Alice and Alice Lake Sites

	Port Alice	Alice Lake
Tree Type:	Douglas Fir	Douglas Fir
Planting date:	1977	1978
Slope:	Southerly, 15 degrees	Virtually Level
Soil:	Light aggregate	Heavy Loam
Data Acquisition Area:	40 by 50 meters	30 by 30 meters
Indicator Plants:	Salal	Salmonberry, Swordfern

The Port Alice site is located in a narrow valley directly in line with and subjected to sulphur emissions from the Port Alice Mill. The Alice Lake site is located about fifteen kilometers east of the Port Alice site in a region of very near normal ambient sulphur levels. The Port Alice site was selected because of the presence of very heavily impacted Douglas Fir. The Alice Lake site was selected because it contained a stand of very vigorously growing healthy Douglas Fir.

Noble metal electrodes were inserted in side branches at breast height within two centimeters of the base of the first year's growth on the main lateral stem at the top of the stem. Electrode residence is in the soft tissue above the woody portion of the stem. Electrode diameter is 150 micrometers. Depth of penetration is about two millimeters in length. Twenty-two trees were monitored, two electrodes in each tree. Electrodes were positioned on the tree in unshaded branches approximately 180 degrees apart. This procedure began on day 204, 1988 at Port Alice and on day 234, 1988 at Alice Lake and will continue until mid year, 1990. The results from the first year of operation are reported in this written paper. Due to human and animal activity at the site, only those electrodes will be used in the analysis which yielded continuous data for the entire first year. This was thirty electrodes at the Port Alice site and thirty-six electrodes at the Alice Lake Site. All potentials described in this paper are with respect to the standard hydrogen electrode.

Index Formation

The characteristics of the **PHYTOGRAM** has led to the formation of distillation algorithms whereby the data taken from each channel each day is converted into a single daily index. In the case of the respiratory activity index, empirical results from various parts of the North American Continent and on different plant types has led to the following algorithm:

PG11 Index = (725 - minimum daily potential), mV

The PG11 index is interpreted as a measure of respiratory activity. The 725 mV is empirically chosen to be an "absolute" minimum. For example, if the minimum potential of a particular electrode during a twenty-four hour period is three hundred millivolts, the PG11 index is 725-300 or 425mV for that particular electrode for that particular day. The index can then be extended to multiple electrodes and over longer periods of time. A PG11 index value of 333 for the Alice Lake site for September 88 would be the average index of the 36 electrodes for the 30 day period.

The autotoxicity index is based on the following algorithm:

PG12 Index = (Potential-725)*(Time above 725 mV, hours)*0.1, mVh

As the excursion above 725 millivolts is greater and of longer duration, the index is greater. If the potential does not rise above 725 millivolts, the index is zero. This index is duration and magnitude sensitive. For example, if the potential of a given electrode was below 725 millivolts for a twenty-four hour period with the exception of two hours during which the potential was 1000 millivolts, the PG12 index is (1000-725)*2*0.1 or 55 mVh. A PG12 index value of 113 for the month of January 1989 for the Port Alice site would indicate that on the average each electrode each day in the month yielded an area under the curve of a hyper-potential\time plot of 1130 or an index value of 113. The factor of 0.1 is ignored in the dimension.

Both indices are determined each day over the twenty-four hour period beginning at midnight. Fortunately, the two indices are independent since the minimum in potential occurs almost always during the early morning hours while the hyper-potentials are present only during the daylight hours.

RESULTS

PG11 Index

The comparative PG11 index for the Port Alice and Alice Lake sites is shown in figure 1 for the time interval from day 235 to day 265, 1988 (22 Aug to 21 Sept). Rainfall elicited a very favorable response and moved the site index value from about 275 up to 400 at Alice Lake, but there was no change at Port Alice.

The winter season was marked by widely varying index values concomitant with a wide range in temperature. The PG11 site index value at Alice Lake reached 480 on day 18, 1989 only to plummet to 201 on day 33 in the midst of a severe outflow of arctic air passing over the Island. The index at Port Alice varied from a high of 335 on day 26 to a low of 175 on day 34.

The form of the distribution density function of the index values at both sites is similar and is approximated by a gamma distribution. The Alice Lake distribution had considerably more branches operating at higher levels than the Port Alice site. A more detailed analysis of the changes in the distribution during the time period from day 235 to day 243 at Alice Lake is shown in figure 2. The distribution shifts from a strong cluster in the two hundred range under relatively unfavorable weather (day 235 to day 240) to a more distributed set of values in response to rainfall (day 241 to day 243). This shift in the distribution characterized the increase in site index values observed during the autumn and early winter. The index cluster value around 210 remained the same, but in these two seasons a greater percentage of the branches performed at higher index values. The index values from two different branches on the same tree yielded no general pattern.

Figure 3 and Table 2 shows the comparison between the monthly index values beginning in August of 88 and extending to August of 89. Acquisition at the Alice Lake site was begun in late August, 1988 and extended to mid June, 1989 at which time an intinerant animal ripped out the electrical ground lead.

The non-normal distribution requires nonparametric tests for significance. Table 2 contains the results from application of the Mann Whitney U and the Cramer von Mises T statistics (Sprent, 1989, Seigel, 1988). The PG11 index values at the two sites were very significantly different throughout the monitoring period with the remarkable exception of May 89 when the two sites converged in their characteristics. The Mann Whitney statistic result must be tempered by the awareness that there was a difference in the variance values at the two sites.

The index values from Port Alice during the summer of 1988 and 1989 were consistent with the general weather pattern. The summer of 1988 was very dry and the summer of 1989 was very wet. The site appeared to respond to the difference with index values

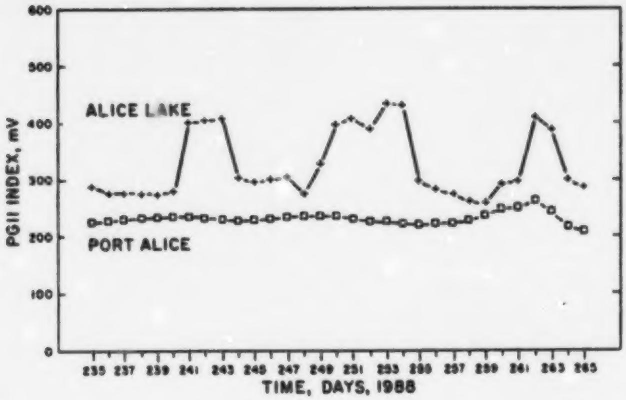

Figure 1. Comparison of the Daily Values of the Site PG11 Index from Day 235 to Day 265, 1988. The Alice Lake site responded to the rainfall disturbances on days 240, 248 and 261.

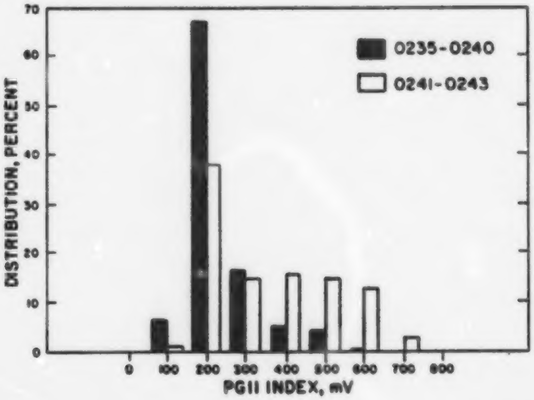

Figure 2. Comparison of the Distribution of the Individual Branch PG11 Indices within the Alice Lake Site before and during a Rainfall Response.

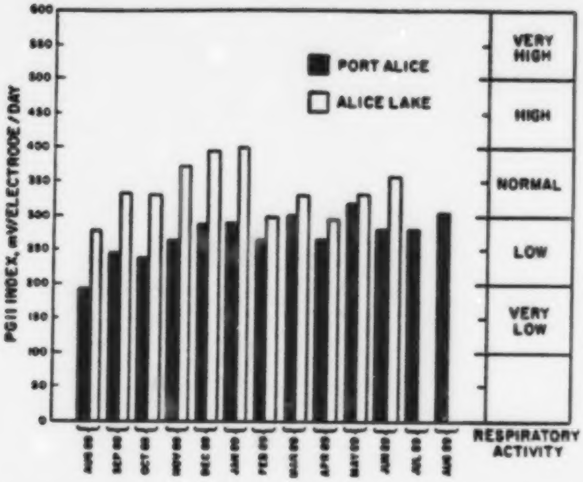

Figure 3. Comparison of the Monthly Site PG11 Index at the Port Alice and Alice Lake Sites from August 1988 to August, 1989.

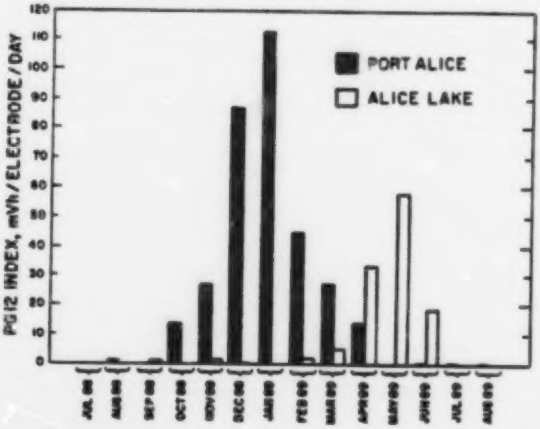

Figure 4. Comparison of the Monthly Site PG12 Index at the Port Alice and Alice Lake Sites from July 1988 to August 1989.

around 225 in 1988 and 285 in 1989.

Table 2: Numerical values and Level of Significance of the PG11 Index at Port Alice and Alice Lake

1988	AUG	SEP	OCT	NOV	DEC			
Port Alice,mV	192	246	238	265	288			
Alice Lake,mV	278	333	331	374	396			
Mann Whitney U,%	-----------<.01----------							
Cramer von Mises T,%								
Sample Size,days	6	30	30	28	20			
1989	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Port Alice,mV	290	267	302	266	319	282	282	307
Alice Lake,mV	402	300	332	296	333	362	na	na
P.A. Std. Dev.,mV				107	126	118		
A.L. Std. Dev.,mV				145	157	152		
Mann Whitney U,%	--<.01--		.08	.1	75	-----<.01----		
Cramer von Mises T,%				<1	<5	<1		
Sample Size,days	30	30	30	30	30	24	30	16

PG12 Index

Some of the plants exhibited very little spiking while others exhibited very prominent spiking. A second major characteristic of the spiking was its presence on one day and absence the next day. It is highly weather sensitive.

Figure 4 gives the comparison of the PG12 index for the two sites over the thirteen month period beginning in July of 1988. The difference between the two sites is very decisive. The Port Alice site exhibits a relatively consistent increase in the spiking levels until a peak is reached in January. Then the spiking gradually diminishes. In contrast to this, the PG12 index value of the Alice Lake site is virtually zero until the early spring. The spiking reaches a peak in May and then decreases. The comparison of the two sites is exact, but the numerical values are truncated in the same manner at both sites due to the use of zinc grounding rods in the acquisition circuitry. The true values are estimated to be about fifteen percent higher at both sites.

DISCUSSION

The data in the figures and tables are based on raw data and indicate a difference in both indices between the two sites without recourse to an interpretation in terms of the underlying bioelectrochemistry. Under the hypotheses described previously, the interpretation can be extended. First of all, the higher level of the PG11 index at Alice Lake would suggest a higher level of respiratory activity during the entire year. At the same time, the respiratory activity at Alice Lake declined very rapidly during the month of January and remained at a reduced level until May. This is consistent with the late spring on Vancouver Island in 1989. There is evidence of an autumn recovery period at both sites from the summer high temperatures and dryness. This recovery appeared to be sustained during the winter, spring and following summer. The index values remained higher than the relatively depressed values during the summer of 1988. This would suggest that there is a adaptability with a time scale of months.

The patterns of activity at both sites indicates a high level of respiration right up until January. The decrease in respiration in mid January was only exacerbated by the severe cold front in early February. This would suggest that a slowdown was coming even before the cold front passed through. This slowdown may be interpreted as a "winter dormancy." But the relatively high levels of the index values even during this period would suggest that any such "dormancy" is modest.

The results from these two sites as well as other sites and plant types in North America has led to the quantitative scale of respiratory activity shown in figure 3. The PG11 site index values from Alice Lake ranged from the bottom of the low activity range (about 200) during the cold front in early February to the top of the active range (about 500) in early January and mid-June. The PG11 index levels at Port Alice also bottomed out during the cold front in early February but did not reach the high activity range at any time. In general, the site PG11 index at Alice Lake was in the normal or active range while the index levels at Port Alice were consistently in the low range with three months in the bottom of the normal range.

The distribution of the index values within a site and even within the same tree indicate a wide disparity in respiratory activity. The increase in the index is a manifestation that a greater percentage of the branches are operating at a higher level, not that there is a consistent increase in the respiratory activity of the entire population.

The daytime timing and seasonal occurrence of the spiking and the attendant high values of the PG12 index are consistent with observations at other sites and with other tree types (Modena et al, unpublished, Gensler, unpublished). Within the hypothesis presented at the beginning of this paper, the high values of the index at Port Alice suggest that the spiking occurs when there is a release of stress and in response to the site trying to "catch up." The interpretation is that the trees at the site were actually being highly adaptive in trying to do in the winter what they were not able to accomplish at other times. This forces them into a high level of electron generation inconsistent with the weather conditions at the moment.

The spiking at Alice Lake occurred at a time of high metabolic activity. Under the assumption of peroxide formation presented above, the level of electron generation was not in concert with the weather conditions at the moment. The very abrupt disappearance of the spiking at Alice Lake in mid-June indicates the electron stream is very likely still there, but the weather conditions were such that the energy is normally directed. The occurrence of spiking in the spring, while deleterious, is interpreted as overactivity of a normal tree.

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THE STATUS OF FROST HARDINESS RESEARCH IN NORTH AMERICAN FORESTRY

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SUMMARY

A brief review is provided describing a number of advances in frost hardiness research in forestry. The review is far from exhaustive, but highlights some of the more important achievements, such as making frost hardiness an established physiological parameter in the evaluation of tree seedling quality. The review is intended to stimulate discussion and give direction to future research, such a membrane studies, the elucidation of the relationship between frost hardiness and dormancy and root hardiness studies.

Key words: Frost hardiness, frost injury, frost testing procedures.

INTRODUCTION

The interest in frost hardiness is continuing to increase as indicated by the ever increasing literature on the subject. Up to the fifties, books on the subject were few (Levitt 1941; 1956; Vasil'yev, 1956). Since then, and especially in the last 20 years, the literature on the subject has increased at an ever increasing rate as indicated by the many books and compendia that have been published (Levitt, 1972, 1980; Li, 1987, Li and Sakai, 1978, 1982; Lyons et al., 1979; Olien and Smith, 1981; Precht et al., 1973) Many of these compendia are proceedings of symposia, which are published in book form.

Although most of the frost hardiness literature deals with agricultural crops there also has been a significant increase in the literature that deals with the frost hardiness of forest trees. This increase reflects an increasing interest in frost hardiness within the forestry community. One example of this increasing interest is shown by the fact that frost hardiness is now one of the accepted physiological parameters that is used to evaluate the quality of tree seedlings (Duryea, 1985, Glerum, 1988, Ritchie, 1984).

CELLULAR RESEARCH

The primary effects of freezing injury are due to cell membrane disruption when ice formation occurs. Hardy tissues survive, because they are able to protect all the cell membranes from the effects of freezing, which is accomplished through a combination of chemical protection and membrane synthesis. Non-hardy tissues do not survive, because of their inability to protect their membranes (Steponkus, 1984).

Since the membranes play such a central role in frost hardiness, many laboratories in North America as well as throughout the world, are spending a considerable amount of their research efforts on membrane studies. They are trying to determine the chemical compounds involved in chemical protection as well as their manner of operation. They are also trying to determine what is involved with membrane synthesis and the restructuring of the membranes during the frost hardening process. In short, the aim is to determine the primary molecular events which are involved in the response of plants to low temperatures.

Considerable progress is being made with these membrane studies, particularly with agricultural crop plants (Lyons et al., 1979; Li, 1987). Although membrane work on tree species, particularly coniferous species, is considerably more difficult than on herbaceous plants, the progress being made is encouraging (Li, 1987). However, definitive answers from these membrane studies will not be forth coming in the near future, simply because of the inherent membrane complexities. This is all the more reason for encouraging long-term research on membranes.

WHOLE PLANT RESEARCH

Frost hardiness studies with intact trees or tree components (i.e. twigs, needles etc.) are many and will continue to be so for years to come. It was this type of work that has led to making frost hardiness one of the physiological parameters for evaluating seedling quality. In several Canadian provinces containerized seedlings are tested for frost hardiness before they are moved from the greenhouse to outside holding areas. When the hardening regime is initiated the top of seedlings are weekly subjected to two freezing temperatures (-10° C and -15° C) until frost hardy. Injury is assessed with the electrical conductivity technique (Colombo et al., 1984, 1989). In British Columbia bareroot seedlings are subjected to freezing (-18°C) prior to being lifted in the autumn for placement in overwinter frozen storage (-2°C). Freezing injury is assessed by examining the foliage for 4 to 10 days (Simpson, 1986). This is in simplified form of the whole seedling assessment method, which is a growth or browning test that was developed by Dr. R. Timmis and others near Centralia, Washington, on the west coast in the 1970's for Douglas fir (Glerum, 1985). In Ontario and Manitoba bareroot seedlings are now determined to be ready for lifting in the autumn with electrical impedance (Glerum, 1985), prior to placement in over-winter frozen storage (-3° C).

The above mentioned assessment methods are the only two methods, which presently, are used on an operational scale (Glerum, 1985). However, every technique has its short comings and these techniques are no exception. The major short coming is that these techniques do not allow for measuring freezing injury to the roots. The importance of healthy, uninjured roots is self-evident, but the measurement of root frost hardiness has many technical and logistical problems. Consequently, over the years, work with roots has not received as much attention by researchers as have the shoots. Presently, the work on root frost hardiness is increasing and the results are encouraging.

It is well known that roots are significantly less hardy than the aerial parts of the tree.

Frost hardiness differences between top and roots can be as much as 20 degrees Celsius or more. Most recently it was observed that the frost hardiness process of stems was different from that of roots. The latter being only affected by temperature (Bigras et al., 1989a). On the other hand, Colombo (pers. comm. 1989) observed that root hardiness is correlated with the phenological state of the bud. He observed root hardening at warm temperatures (24°C/16°C) but roots attained greater hardening at cooler temperatures (10°C/5°C). One of the reasons for these differences in observations may be due to differences in the plant material used. Bigras et al. (1989a) used rooted juniper cuttings, while Colombo used 24-week-old black spruce seedlings. Another reason is that their root terminology differs. Bigras et al. divided the root system into mature roots and young roots, while Colombo divided the root system into coarse roots (i.e. diam. >1.0 mm.) and fine roots (i.e. diam. <0.5 mm.). There is a need for standardizing the root terminology. Bigras et al. (1989b) observed that mature roots hardened significantly while young roots did not harden. Colombo observed that the coarse roots hardened significantly, while the fine roots did not harden appreciably. Maximum root hardiness observed by Colombo was at -20°C, which is comparable to -18°C observed by Bigras et al. (1989b).

The differences in frost hardiness between roots and stems has been referred to as differential frost hardiness, which is inherent to all our trees (Glerum 1976, 1985). It is these differences in tissue hardiness that make it extremely difficult to assess total tree damage. We observed recently another example of this differential hardiness in 8-year-old outplanted jack pine and black spruce (Glerum and Paterson, 1989). Both of these species had an equal number of frost rings in their xylem, about one every year since planting. However, the spruces suffered lethal freezing damage to the current year's terminal shoot, while the pines did not. The presence of these frost rings demonstrate that the active cambium of both species is equally sensitive to frost, and the cortical cells of the spruce are just as sensitive but, the cortical cells of the pine are considerably more hardy. This explains why spruces frequently lose their terminal leader dominance due to frost, while pines do not.

As mentioned elsewhere (Glerum, 1976; 1985), the elucidation of the relationship between frost hardiness and dormancy will have many practical implications. As Colombo (1989) points out, the existence of this relationship, whether functional or temporal, has been the object of speculation by several investigators. In a study with 1-year-old black spruce containerized seedlings, Colombo (1989) observed a curvilinear relationship between dormancy and frost hardiness. The seedlings were fully dormant (i.e. rest) at the time of bud initiation and frost hardiness was low (-7°C). By the time frost hardiness was high (-40°C), the seedlings were ready to come out of dormancy (i.e. imposed dormancy).

In this same study, Colombo (1989) observed increasing shoot frost hardiness up to -40°C without the necessity of cold temperature exposure. Colombo's observations are in agreement with those of Christersson (1978).

CONCLUSIONS

It can be seen from the above abridged overview that considerable progress in frost hardiness research has been made. However, it is also clearly evident that much remains to be discovered concerning the frost hardines of forest trees. There is no doubt that the years ahead will be challenging and rewarding. The membrane studies are just beginning. The elucidation of the dormancy-frost hardiness relationship has just been initiated. The frost hardiness of roots and all the factors (both internal and external) that influence it, require long and dedicated research efforts. Furthermore, pollution (e.g. acid precipitation) and global warming, which have not been addressed in this paper, will affect the frost hardiness process of forest trees. Only with a sound understanding of frost hardiness can these deleterious effects be minimized. As a frost hardiness researcher in forestry, one can only be optimistic for the years ahead.

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EFFECTS OF LATE SUMMER PHOTOPERIOD UPON SOME ASPECTS OF THE PHYSIOLOGY OF SEEDLINGS OF SEVERAL BOREAL SPECIES

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SUMMARY

First year seedlings of white spruce (*Picea glauca* (Moench.) Voss), black spruce (*Picea mariana* (Mill.) B.S.P.), lodgepole pine (*Pinus contorta* Dougl. and jack Pine (*Pinus banksiana* Lamb.) were grown under either sixteen hour, natural, or eight hour photoperiods during the month of August. Both prior to and after the photoperiod treatments, all conducted under ambient temperatures in the Vancouver area, seedlings were grown under ambient photoperiods and temperatures. Exposure to short photoperiods generally increased seedling cold hardiness and field survival after outplanting in mid-October, but abscisic acid (Aba) content varied with species and treatment.

Keywords: Photoperiod, cold hardiness, coniferous seedlings, abscisic acid

INTRODUCTION

Good plantation survival in the boreal forests of interior British Columbia requires seedlings of high physiological vigour, good planting practices and effective site preparation. This paper is concerned with factors affecting the first of the foregoing, physiological vigour. Lavender (1980, 1989) discusses research which demonstrates that short photoperiods generally stimulate the cessation of shoot growth of seedlings endogenous to boreal forests and Weiser (1970) notes that the development of cold hardiness in perennial woody plants occurs only after shoot elongation has ceased. Recent reviews (Lavender and Silim, 1987, Johnson, 1987, Sakai and Larcher, 1987, Reaney et al., 1989, and Junttila and Kaurin, 1989) all present data which relate the development of cold hardiness to levels of plant growth regulators, particularly Aba. However, these workers cite very few data derived from trials with conifers. And Lavender and Wareing (1972) and Lavender (1989) note that during late summer and early fall the stress resistance of temperature zone conifers may be dramatically affected by photoperiodic treatments. Accordingly, the research discussed in this paper was initiated to determine the effects of photoperiod during the late summer upon the development of cold hardiness, the levels of endogenous Aba, and the general stress resistance of seedlings, as reflected by survival after outplanting in mid-October, of several boreal species.

EXPERIMENTAL METHODS

Seeds of white spruce and lodgepole pine from British Columbia and of white spruce, black spruce and jack pine from Ontario were germinated in 313A styroblocks (ca 62 cc volume/cavity, 936 cavities/m^2) at the U.B.C. nursery in Vancouver and grown according to methods prescribed by the Ministry of Forests (van Eerden and Gates, 1990) during the summer of 1988. The seedlings were maintained in an open, unheated greenhouse during the entire growth period and, hence, were subject to ambient temperatures. On August 1 seedling populations were divided into thirds, with each third receiving one of the following photoperiods for the entire month of August: natural photoperiod (ca sixteen hours on August 1, ca 14 hours on September 1) sixteen hour daily photoperiod (natural photoperiod supplemented with incandescent light of ca 0.05 Em^{-2}, s^{-1}, an intensity previously shown to be effective in stimulating photoperiodic responses in conifers (Arnott, 1978, McCreary et al. 1978) at the end of the natural photoperiod), or an eight-hour daily photoperiod. On the 1st of September, the photoperiod treatments ended and all seedlings remained under ambient conditions until they were either shipped to an outplanting area near Williams Lake, B.C. in mid-October or placed in cold storage (ca 1^{o} C.) in early February. Seedlings were removed from cold storage in early May and shipped to Williams Lake for outplanting.

Samples of seedling foliage to be employed in determinations of endogenous Aba were harvested at the beginning of the photoperiod on 9 September and again on 23 March. Such samples were immediately placed in liquid nitrogen and then transferred to storage at -80^{o} C. until the analysis procedures described in Kannangara et al. (1989) were carried out.

Samples of seedling foliage which were employed to estimate seedling hardiness were harvested on 20 November 1988. The procedure of Hallam and Tibbits (1988) which utilizes the concentration of materials leached from cells damaged by freezing was employed to estimate the degree of damage occasioned by each test temperature. These data were then evaluated graphically to estimate the LT_{50} for each seedling population and treatment.

Seedlings outplanted near Williams Lake were planted in a randomized block design for each planting season. One row of twenty seedlings for each species and treatment was planted in each of four blocks for a total of eighty seedlings per species and treatment in both the fall and spring plantations. The sequence of rows was randomized independently for each block. Seedling phenology, growth, and survival were recorded during the 1989 growing season. Only the final seedling survival will be discussed in this paper.

RESULTS

The data in Tables 1 and 2 suggest that the levels of abscisic acid definitely vary between the experimental populations, with no consistent effect of photoperiod of season of the year. Other data for woody species reviewed by Lavender and Silim (1987) also demonstrate no effect of photoperiod per se, although most reports indicate a maximum level of abscisic acid during the winter period.

Table 1. Concentration of Abscisic Acid in Seedlings of Several Boreal Species in September.

	Concentration of Abscisic Acid (ng/gm) Treatment		
Species	Natural Day	Short Day	Long Day
Lodgepole pine	55 a	81 a	---
White Spruce (B.C.)	56 a	42 b	---
White Spruce (Ont)	61 a	37 b	---
Black Spruce	75 a	113 a	280 b
Jack Pine	81 a	101 b	136 c

Data in the same row followed by the same letter not significantly different (0.05)

Table 2. Concentration of Abscisic Acid in Seedlings of Several Boreal Species in March.

Species	Concentration of Abscisic Acid (ng/gm) Treatment		
	Natural Day	Short Day	Long Day
Lodgepole Pine	86 a	137 b	---
White Spruce (B.C.)	49 a	42 a	---
White Spruce (Ont.)	45 a	50 a	50 a
Black Spruce	135 a	125 a	232 b
Jack Pine	137 a	431 b	317 b

Data in the same row followed by same letter not significantly different (0.05)

In contrast to the above, the data which indicate the estimated maximum cold hardiness of seedling populations (Table 3) definitely reflect the August photoperiod treatment with lower LT^{50}'s for plants receiving the eight hour daily light period. This pattern of cold hardiness development is similar to that reported for a number of woody species by Sakai and Larcher (1987).

Finally, the pattern of seedling survival for populations outplanted in the fall (Table 4) is very similar to that of the levels of cold hardiness shown in Table 3.

Table 3. Estimated Lethal Temperatures (LT^{50}'S) for Seedlings of Several Boreal Conifers Exposed to Different Photoperiods During the Month of August in mid-November.

Species	Photoperiod		
	Eight hours	Natural	Sixteen Hours
Lodgepole pine	-28	-25	--
White Spruce (B.C.)	-40	-30	--
White Spruce (Ont)	-55	-40	-25
Black Spruce	-55	-35	-20
Jack Pine	-40	-30	-25

Table 4. Mortality of Fall Planted Seedlings of Several Boreal Species.

Species	Mortality Per Cent Treatment Natural Day	Short Day	Long Day
Lodgepole Pine	41	1	--
White Spruce (B.C.)	0	0	--
White Spruce (Ont)	0	0	--
Black Spruce	0	0	5
Black Spruce	0	0	32
Jack Pine	20	5	49

Table 5: Mortality of Spring Planted Seedlings of Several Boreal Species

Species	Mortality Per Cent Treatment Natural Day	Short Day	Long Day
Lodgepole Pine	6	0	--
White Spruce (B.C.)	0	0	--
White Spruce (Ont)	0	0	0
Black Spruce	0	0	2
Jack Pine	0	0	1

DISCUSSION

The data presented in this paper clearly demonstrate that cold hardiness development in the experimental populations was definitely promoted by a period of short photoperiods in late summer. These data are in agreement with the results of similar trials reported by McCreary *et al*. (1978) for Douglas-fir seedlings. The levels of cold hardiness achieved by seedlings exposed to the different photoperiods are not, however, correlated with levels of Aba nor is the degree of cold hardiness achieved by seedlings of the different species correlated with the endogenous Aba content of that species. This lack of correlation may reflect a lack of participation of Aba in the cold hardening process, or it may reflect a relationship between not the absolute levels of Aba and cold hardiness but a correlation between cold hardiness and relative levels of Aba and other growth regulators such as gibberellic acid as discussed by Reaney et al. (1989). We do not have data describing the endogenous levels of gibberellic acid of our populations, so can neither confirm nor refute this hypothesis directly. However, portions of the populations of this study were sprayed daily at the end of the photoperiods with solutions of 100 micromolar Aba or 100 micromolar of a mixture of gibberellic acid, zeatin, and indole acetic acid (seedlings reported in tables 1 - 4 were sprayed with pure water at the same time). Such treatment with Aba generally resulted in slightly lower lethal temperatures than those of water treated seedlings and sprays of the promoters resulted in slightly higher lethal temperatures. These effects, however, were minor compared with the effect of the photoperiod per se. Further, limited evaluations of the seedlings sprayed with the mixture of promoters evidenced a great enhancement of the endogenous Aba levels of the treated plants. Accordingly, evidence from our trials does not support a hypothesis that the tested plant growth regulators are strongly involved in the physiology of cold hardiness.

The similarity in pattern of cold hardiness and field survival of seedlings outplanted in October, together with the lack of mortality of similar seedlings outplanted at the same time in the nursery area at the University of British Columbia in Vancouver suggest strongly that the seedling mortality was occasioned by low temperatures and not by a general lack of stress resistance as has been shown for a number of other species, particularly Douglas-fir and pines, (Ritchie, 1989, Sutton, 1984, Lavender, 1989). And the increased survival of seedlings exposed to short photoperiods is in agreement with data for lodgepole pine and white spruce presented by Silim et al. (1989).

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FROST HARDINESS ASSESSMENT: NEW DEVELOPMENTS

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SUMMARY

The impedance method has been developed in the direction of impedance spectroscopy. The aim is to characterize plant tissues using an electrical model and to find out more exactly the site of frost damage. Using the impedance locus presentation a new electrical model for a small-diameter stem of Scots pine was developed. The type of needle electrodes, degree of hardiness and frost damage significantly affected the form of impedance locus.

Keywords: electrical model, electrode, impedance analysis, impedance locus, Scots pine.

INTRODUCTION

Living cells constitute resistive and reactive components which form electrical impedance of alternating current. The reactive components are mainly connected to cell membranes whereas resistive characteristics are explained by intra- and extracellular solutions. Many investigations have shown a decrease of the impedance modulus, or its derivatives, after damage (van den Driessche 1969, Glerum and Krenciglowa 1970, Pelkonen 1984, Repo and Pelkonen 1986, Repo and Lappi 1989).

Previous studies indicate that the impedance modulus and impedance phase angle change with frequency, the latter being negative at at least 1 MHz frequency (Evert 1973, Stout et al. 1987). This proves the reactive components to be capacitive in character. Due to some physical and physiological factors affecting the impedance characteristics, the predictive power of this method has not been beneficial when compared with e.g. electrolyte leakage test or visual inspection. In this paper we are characterizing and analyzing the impedance locus of Scots pine (*Pinus sylvestris* L.) stems. The model has been presented in order to find the excact site of frost damage.

EXPERIMENTAL METHODS

Resistive and reactive parts of the impedance were measured over the frequency range from 20 Hz to 1 MHz with an impedance analyzer (HP 4284 A). Different sizes and types of needle electrodes were tested to find the best electrode material for the measurements. The following type of needle electrodes were used:

Electrode material	Electrode diameter, mm
Stainless steel	0.6
Chloridized silver	0.6, 1.0
Silver coated brass	1.0
Zinc	0.7
Copper coated steel	0.8
Silver coated steel (acupuncture needle)	0.3
Silver	0.5, 0.75, 1.0
Gold	0.5

Table 1. The types of needle electrodes used in the tests.

The study material consisted of the stems of previous and current year's shoots from approximately 10 years old Scots pine trees. The electrode impedance was determined for steel needle electrodes by varying the inter-electrode distance (Schwann 1968). The resistive and reactive parts of electrode impedance measured against frequency were obtained by interpolating the lines to the inter-electrode distance of zero. Up to now the significance of electrode impedance in other study cases has been estimated by comparing the impedance loci. The stems of small diameter Scots pine (d=2-4 mm) were simulated with different kinds of electrical models. The Nelder-Mead-algorihm of Matlab-software was used in the estimation. The best fit between measured and calculated impedance characteristics was found with the model in Fig. 1.

The RC-circuits C and D were further divided into two series of five RC-circuits (Fig. 2a) in a way that in both series a resistance formed a normal distribution around a mean of a capacitance (Fig. 2b). Cumulative value of multiplication factors of resistances was one.

The parallel circuit (A, Fig. 1) of a resistance and a capacitance describes electrode impedance. Component B is still a "black box" which includes both frequency independent resistive and capacitive components (R_1 and X_1) and frequency dependent resistive and capacitive components (R_2 and X_2). The component B was simulated with equation:

$$Z_B=R_1+X_1\cdot i+(R_2+X_2\cdot i)\cdot \log f \qquad (1)$$

where Z_B is the impedance of the component B, i is the imaginary unit and f is the frequency.

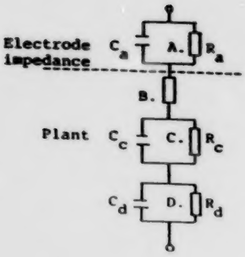

Figure 1.

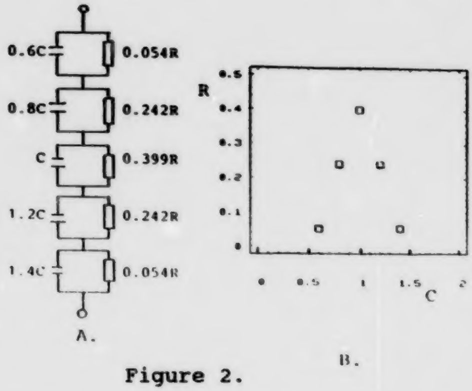

Figure 2.

Figure 1. An electrical model to simulate the stem of Scots pine.

Figure 2. A. Substitution of the RC-circuits, C and D in Fig. 1, with a series of RC-circuit. B. Distribution of multiplication factor of resistance with capacitance.

RESULTS AND DISCUSSION

The type of electrode significantly affected the impedance locus. The reactive part of impedance of the unhardened stems, measured with steel electrodes, was about -12 kOhm at 20 Hz, and increased with frequency (Fig. 3a). However, with Ag/AgCl or Ag-coated brass electrodes the reactive component was about -4 kOhm at low frequencies, and it was seen to decrease with increasing frequency. The result suggested that the latter type of electrodes would have a smaller electrode impedance.

When the frost hardened samples were measured the most promising results were obtained with Ag and Cu-coated steel electrodes (Fig. 3 b). These type of electrodes are not yet tested in measurements of unhardened samples. The resistive and reactive part of electrode impedance of the steel electrodes decreased and increased, respectively, with increasing frequency (Fig. 3 c) (cf. Stout et al. 1987).

The degree of damage strongly affected the impedance locus. As a result of slight damage the overall shape of the locus was retained although the resistive component decreased and the reactive component increased (Fig. 4). Due to serious damage the shape of the undamaged locus disappeared and the impedance characteristics changed drastically. The locus of the frost hardened sample differed significantly from the unhardened one (Fig. 5). The magnitude of both the resistive and reactive component increased, and the relation between the minima of the loci reversed.

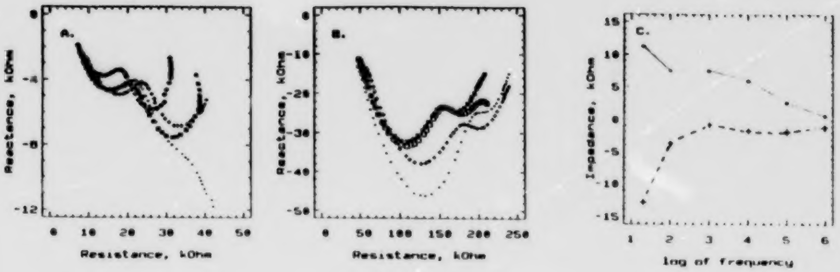

Figure 3. Impedance loci of stems of Scots pine measured with different kinds of electrodes. A. Previous year's stem was measured during the growing season with steel (•), Ag/AgCl (d=0.6 mm) (+), Ag/AgCl (d=1.0 mm) (*) and brass coated with Ag (◇). B. Current year's stems measured in the late autumn with Ag (d=0.5 mm) (□), Ag (d=0.75 mm) (+), Ag (d=1.0 mm) (*) and Cu coated steel (•). Inter-electrode distance was 15 mm. C. Resistive and reactive components of electrode impedance for steel needle electrodes as a function of frequency (unhardened sample).

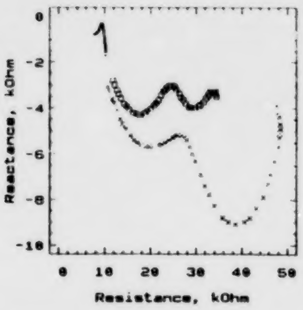

Figure 4.

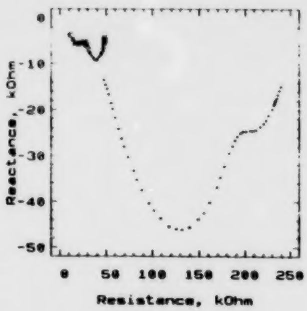

Figure 5.

Figure 4. Impedance locus of an uninjured (×) (d=4.0 mm), a slightly damaged (□) (d=4.0 mm) and a seriously damaged (•) stem (d=4.3 mm) of an unhardened previous year's shoot of Scots pine measured with Ag-coated brass electrodes.

Figure 5. Impedance locus of an unhardened, undamaged (×) (d=4.0 mm) and hardened, undamaged one-year-old stem (d=3.1 mm) of Scots pine measured with Ag-coated brass and Ag electrodes (d=1.0 mm), respectively. Inter-electrode distance was 15 mm.

Both the reactive component and the impedance phase angle were negative at all frequencies studied which suggests that there are no inductive components in the samples. According to a preliminary analysis of the loci they are formed of at least two semicircles which suggest that the electrical model behind the stem includes at least two time constants. The circles seem to have depressed centers, i.e. the centers stay at the range of positive reactance. This phenomenon has been explained with several time constants for a single dispersion range (Schanne and Ruiz-Ceretti 1978, pp. 55-56, cf. Schwan 1963).

The best fit between measured and calculated impedance characteristics of a previous year's stem of a Scots pine was obtained with the model shown in Figs. 1 and 2 also using the model of Equ. 1 (Fig. 6). In the best fit the following parameter values were obtained: R_1=91.5 kOhm, X_1=-13.6 kOhm, R_2=-10.7 kOhm, X_2=1.3 kOhm, R_a=9.7 kOhm, C_a=0.66 µF, R_c=37.6 kOhm, C_c=57.9 kOhm, R_d=8.1 kOhm and C_d=1.1 nF.

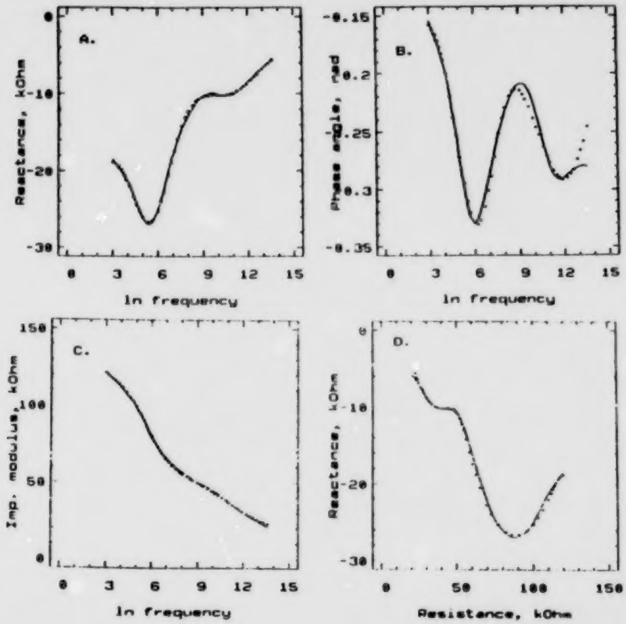

Figure 6. An example of the measured (•) and predicted (line) impedance characteristics of an uninjured and unhardened stem of Scots pine. A. The reactive component as a function of frequency. B. Impedance phase angle as function of frequency. C. Impedance modulus as a function of frequency. D. Impedance locus.

In the following studies, when we have a series of impedance loci, measured from stems with different degrees of damage, we might be able to estimate a model for each locus. With the changes of parameter values we hopefully can estimate damage in different tissues. As a conclusion the impedance locus presentation seems much more informative in studies of frost damage than the measurement of the impedance modulus or resistive component at one frequency only.

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THE GENETIC RESOURCES OF PINUS PEUCE Grsb. IN BULGARIA

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FDC: 165.3: 174.7 Pinus peuce Grisib.: (497.2)

SUMMARY

The eastern locality of Pinus peuce Grsb. on the Balkan Peninsula, is situated in Bulgaria, and it is represented by large populations that occur in the Pirin and Rila Mountains. In the Central Balkan Range, the West Rhodopes, Vitosha, and Slavyanka it comprises smaller, single formations; or occurs as individual trees. This tertiary relict occupies 14,000 ha within the range from 1400 (1500) up to 2200 (2300) m alt. where it forms either pure, or mixed stands, most often with Pinus sylvestris L., Picea abies (L.)Karst., Pinus heldreichii Christ. and Pinus mugo Turra.

Its variation in main phenotype features such as: branch pattern, habitus, bark cracking, strobile colouration, etc.,has been studied. Its form of spindle-shaped crown, horizontal branches, and plate-line bark is the most productive one, for the purposes of tree-breeding.

The genetic resources of this species are conserved mainly in situ: in National parks - 5028 ha, in reserves - 584 ha,and in seed-producing stands - 626 ha. One hundred and fifty-two candidate-elite trees, of superb growth and resistability, have been selected, yet their progenies have been tested under three types of ecological conditions.

EXPERIMENTAL METHODS AND RESULTS

Pinus peuce Grsb. forms its most productive stands in the upper part of the mountain belt and in the alpine belt, within the range from 1600 up to 1900 m alt., where its optimum is. This species is very resistant to unfavourable climatic effects, and it is most suitable for stabilizing the upper forest limit with. These properties, as well as its valuable timber, make it extremely suitable to be bred, under the abovementiones conditions. Besides, its high resistability to pests and diseases, incl. Cronartium ribicola and Armilaria mellea, allows this pine successfully be applied in interspecies hybridization with some five-needle pines, for to combine this feature with their high growth rates.

During the period 1971-1976, on 19 plots of different sites, all near to the upper forest limit in the Balkan Range, the Rila Mountains, Osogovo, and the Pirin Mountains, experimental plantations on P. peuce - population base were established on 27 ha.

In the recent years, studies on the state of the genetic resources of Pinus peuce have been carried out for the purposes of its breeding, in all the mountain massives (the Pirin and Rila Mountains, the Balkan Range, the West Rhodopes, and Slavyanka), where this species naturally occurs. All the natural area of Pinus peuce in this country, was investigated, according to mountains, to populations at various altitudes for their corresponding profiles, and to isolated formations. Each sample plot was comprised of up to 200 trees in a population, and it used to provide seeds from 15 representative individuals in seed years. In this study various methods such as: biometrical, phenological, early testing, progeny trials, etc., were applied, with respect to characterizing genetic resources and to determining the possibilities for breeding.

The contemporary flora of the Balkan Peninsula was differentiated at the end of Pleocene. In the beginning of Myocene, Pinus peuce had almost thoroughly occupied, together with the other conifers, the mountainous parts of the peninsula (Stefanoff, 1943). Tectonic processes resulted in the formation of mountain ranges, yet the factors of genetical dynamics determined the spreading and differentiation of corresponding phytogeographical centers. As climate progressively turned continental in Pleocene, this determined the vertical spreading of P.peuce, in the higher parts of the mountains, where air humidity had been higher. The Balkan Peninsula was slightly influenced by freezing in Pleistocene, so it appeared to be a refuge for a great number of forest-tree species. Favourable conditions for the developement of coniferous vegetation incl. Pinus peuce populations had existed in the Rilo-Rhodopean Massif, due to the moist and chilly climate there. The paleobotanical and palinological studies on this species (Stefanoff, Yordanoff, 1935;Bozhilova, 1986), as well as its present condition, indicate that from the Tertiary Period till today, it has constantly been subjected to narrowing its primary natural area and to localizing its formations, because climate has been turning continental. In the course of History, Pinus peuce's natural area has been reduced, due to anthropogenic activities. The habitual cutting and burning down of Pinus peuce forests in the past, for enlarging alpine pasture grounds and for harvesting top-quality building timber, had significantly contributed to this process. It had been very intensive in the last 100-150 years.

In Bulgaria, Roumelian pine (Pinus peuce Grsb.) occurs in its eastern locality which includes large complexes in the Pirin Mountains, isolated populations in the Central Balkan Range and the West Rhodopes, while in Vitosha and Slavyanka it occurs in groups, or as single trees. Similar stands in some mountains of the Dinary System in Yugoslavia and Albania, as well as isolated formations in the North-Greece mountains, belong to its western locality.

The morphological features that determine the Pinus peuce in Bulgaria as var. vermiculata J. are its shorter and thin needles, and its shorter strobiles (Chernyavski et al., 1959).

The Roumelian pine forests in this country occupy 14 000 ha within the range from 1400 (1500) up to 2200 (2300) m alt. The most integer complex of this species is in the Pirin Mountains, and its area amounts to 7175 ha. It consists of two parts: Northeastern - of 3775 ha with its vertical ocurrence from 1600 up to 2200 m alt., and Southwestern - of 3400 ha within the range from 1700 up to 2100 m alt.

In the Rila Mountains, Pinus peuce grows on an area of 6230 ha which includes three complexes: northern, southern, and central. The first one occupies 3684 ha where this pine has formed mainly mixed stands with Pinus sylvestris L., Picea abies (L.) Karst., and Pinus mugo Turra., thus reaching 2100 m alt. The southern complex' area amounts to 1635 ha within the range from 1700 (1800) up to 2100 (2200) m alt. The central one, with its area of 911 ha in the Rilska river valley is distinguished mainly for mixed forests, too, and it reaches up to 2000 m alt. This occurence indicates that the upper forest limit, in the inner parts of the Rila Mountains, reaches lower, and the vegetation's mixed aspect there, is expressed better than it is in the margin. So, in spite of the anthropogenic activities that have effected the present state of the Pinus peuce forests in the Rila Mountains, their occurence agrees with the general regularities of autochthonous development.

In the Rhodopes, Roumelian pine has been localized only in their morthwest spur, on an area of 170 ha, mainly as plantations. To the east and to the south its participation is reduced just to single trees.

In Vitosha, Pinus peuce occupies an area of 104 ha, mainly as plantations that have been grown for more than 60 years, besides, their growth has been good and their viability high. Its natural occurence refers to single trees in the spruce stands that form the upper forest limit.

The northmost formation of this species, as in Bulgaria, so on the Balkan Peninsula, is in the Central Balkan Range. It consists of two parts of a total of 193 ha. The formation in Slavyanka, whose area can hardly reach 57 ha, is among the smallest ones.

Inspite of the complete spatial isolation that exists nowadays between the Rila-Rhodopean Massif, Vitosha, and the Central Balkan Range, the occurrence of a number of plant species incl. Pinus peuce, evidences of the availability of phytogeographical links between them. The Rila-Rhodopean Massif being in a phytogeographical contact with the adjacent mountain massives in Greece and in Yugoslavia, appears to be the start center to the spreading of Pinus peuce in Bulgaria.

Pinus peuce Grsb. is distinguished for its high resistability to extreme climatic effects, windthrows, windbreaks, snowthrows, and snowbreaks. It is extremely resistant both to insect pests and fungus diseases. Its biological resistability is combined with high productivity. It shows highest rates of growth in height, between the ages of 20 and 40. Its growth in diameter is shown to be most intensive between the ages of 30 and 80. At the abovementioned ages, the current increments in height and in diameter vary from 20 up to 46 cm, and from 1.6 up to 3.8 mm resp., and the annual increment in volume - from 4.3 m^3/ha up to 13.2 m^3/ha, according to site conditions (Nedyalkov and Krâstanov, 1962).

The high densities of mature Pinus peuce stands result in increasing the basal area and the volume per ha. The data about the North Pirin Mountains, where a volume of 1672 m^3/ha, an average height of 40 m, and a diameter of 2 m had been measured for 500 years old trees (Nedyalkov and Nickolov, 1986), characterized this.

Roumelian pine occurs mainly on silicate terrains and to a lesser extent on carbonate ones where it forms the corresponding edaphotypes.

While conducting the investigations on the variability of this species, taking crown habitus as criterion, the following forms were determined: 1. With spindle-shaped crowns (f.vermiculata). It occurs at higher altitudes, mainly on sunny expositions, on humus-and-carbonate soils. Individuals, whose strobiles are red before maturation, predominate. 2. With cone shaped crowns (f. conica). It occurs on sites of lower altitudes, mainly on shady expositions, on silicate terrains. Individuals, with green strobiles, predominate. 3. With column-shaped crowns (f.columnaris). Crowns are narrow - from 1 up to 2 m, and branches are short and thin. This is a high-productivity form, because of the many stems per unit of area. Its decorative value is high, too.

According to branching habit, three forms are distinguished: horizontalis, pyramidalis, and pendula. Analogous to the other pine species, the forms of Pinus peuce determined according to this feature, have morphological characteristics that have resulted from continuous adaptation to particular ecological peculiarities.

The forms determined according to branching habit are closely related with these, that are determined according to crown habitus and their appearance is submitted to the law of homologous raws for hereditary variation.

According to bark cracking, the following forms have been determined: 1. Smouth-barked; 2. Scale-barked; 3. With spruce-like-cracked bark; 4. With longitudinally plate-like-cracked bark.

According to colouration of strobiles three forms can be observed: var.chlorocarpa, var.erythrocarpa,and var.dichlora.The first one occurs mainly at lower altitudes and on warmer sites. Its growing season and florination start about 10 days later,yet its growth is slower.

The most productive P.peuce form is with spindle-shaped crowns, plate-like-cracked bark, and red young cones. For determining heritabilities in some quantitative features and for studying the structures of P.peuce populations, half-sib progeny trials have been established, under 3 types of ecological conditions. These experiments involve progenies of 180 individuals of 13 provenances.

National parks and reserves are among the most reliable means for in situ conservation of genetic resources. In Pirin National Park 4924 ha of best conserved stands of P.peuce are included. They consist of central populations in habitats representative for the optimum of this species, and of marginal ones, that have adapted themselves to extreme conditions. A large area of the Roumelian pine complex in the Pirin Mts. helps the restriction of gene migration and of genetic drift, as well as the establishment of climax balance in the places where it has been disturbed by anthropogenic activities. The Bayuvi dupki Biosphere Reserve is included there, too. In it Roumelian pine is located between 1800 and 2200 m alt. on a total area of 259 ha.

The Rila formations that are most representative for P.peuce are included in 5 reserves: Skakavitsa, Skakavets, Ibar, Marichini ezera and Parangalitsa. As most of the Roumelian pine stands in the Rila Mts. are parts of erosion controlling and recreational forests, watersheds,etc., their gene pool has been relatively well conserved.

The greater part (159 ha) of the unique P.peuce formation in the Central Balkan Range is in Tsarichina Biosphere Reserve.

The National Parks and Reserves in this country involve 5249 ha of P.peuce stands which conserve the heterozygosis of this species,as well as possibilities for its evolutional development.

Roumelian pine genetic resources are successfully conserved through in situ method in other 108 seed stands of a total area of 626 ha. Besides,the selected 152 candidate-elite trees of P. peuce and their progenies that grow under 3 different types of ecological conditions, provide a supplementary reserve stock for the conservation of the gene pool for this species.

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GENETIC VARIATION IN ROOT MORPHOLOGY OF Pinus ayacahuite AND Pinus chiapensis

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FDC: 232.12: 164.3: 174.7 Pinus spp.

SUMMARY

Seedlings from 7 provenances and 61 half-sib families of Pinus ayacahuite and Pinus chiapensis were raised in 1 liter containers in a greenhouse and assessed at 25 cm shoot height for lateral root surface area, number of lateral roots, lateral root length and root/shoot ratios. Seedlings of subtropical hard pines, Pinus maximinoi and Pinus tecunumanii were included as controls. Lateral root surface area as a percent of total root surface area of hard and soft pines was approximately the same, 91.5% vs. 89.5%, but Pinus ayacahuite and P. chiapensis had 15% less fibrous root surface area than did P. maximinoi and P. tecunumanii. Slow growing provenances of Pinus chiapensis from elevations above 1500 m had significantly greater lateral root surface area/unit of shoot height than did fast growing provenances from elevations below 800 m. Significant family differences for both Pinus ayacahuite and P. chiapensis were found for lateral root surface area, number of lateral roots, and lateral root length but not for root/shoot ratios. Genetic gains in lateral root development are possible through family and within family selection. Breeding efforts need to be combined with improved nursery techniques to produce more hardy trees.

Key Words: lateral roots, fibrous roots

INTRODUCTION

Pinus ayacahuite Ehrb. and P. chiapensis (Mart). Andresen are white pines endemic to Mexico and Central America. Both species have been established in pilot plantings throughout the tropics and subtropics and appear to have good potential on sites with well drained soils that receive abundant precipitation (Dvorak and Brouard, 1987; Poynton, 1976). However, on sites that are slightly less than ideal, the initial growth of both species is very slow and first year field survival has been poor. Mortality is often attributed to a combination of drought stress and poor root development. If trees survive the first several years, they capture the site and grow rapidly, thereafter.

The objective of this study was to quantify the magnitude of genetic variation that exists in the root morphology of Pinus ayacahuite and P. chiapensis. If a large genetic component is present, tree breeders can manipulate it to develop white pine trees that are better adapted to marginal sites in the tropics.

EXPERIMENTAL METHODS

Seeds of Pinus ayacahuite and Pinus chiapensis were collected from 61 trees and 7 provenances in Mexico, Guatemala and Honduras by the Central America and Mexico Coniferous Resources Cooperative (CAMCORE), North Carolina State University. The provenances sampled were those that best represented the climatic and edaphic extremes in the species range (Table 1). Seeds were germinated in the greenhouse and 24 plants/family were pricked into 1 liter (7.5 cm x 7.5 cm x 18 cm) containers and arranged in a randomized complete block design with 3 replications. Seedlots of the hard pines Pinus maximinoi H. E. Moore and P. tecunumanii (Mart.) Eguiluz and Perry were also included in the study as controls. Seedlings were destructively sampled when provenance shoot height average 25 cm, the normal size at which seedlings are outplanted to the field in the tropics. Shoots were oven dried at 70° C for 72 hours and weighed to the nearest .001 gm. Root systems were gently washed and the length of the 5 longest primary lateral roots measured to the nearest mm. The total number of primary lateral roots were counted. The surface area of the lateral roots and tap roots was measured using an automated system (Delta-T, Dacagon ®). The surface area of fibrous roots was also determined for 50% of the samples from 2 populations of each species. A fibrous root was defined as being 40 mm or less in length and less than 1 mm in diameter. Root dry weights were obtained using standard procedures.

Analyses of variance were conducted using the General Linear Model of the Statistical Analysis System ® for the following traits: lateral root area/shoot height, length of the 5 longest lateral/shoot height, number of laterals, and root/shoot ratio.

Table 1: Location of the *P. ayacahuite* and *P. chiapensis* seed collection sites in Mexico and Central America.

Species	Provenance	Country	Latitude	Elevation (m)
P. ayacahuite	Ixtlan,	Mexico	17° 24′ N	2600
P. ayacahuite	Las Trancas	Honduras	14° 07′ N	2300
P. ayacahuite	Ocotopeque	Honduras	14° 25′ N	2150
P. chiapensis	Barillas	Guatemala	15° 48′ N	1600
P. chiapensis	Nopoala	Mexico	19° 54′ N	800
P. chiapensis	San Gabriel	Mexico	16° 11′ N	1600
P. chiapensis	Tutla	Mexico	17° 25′ N	500

Results indicate that the total root surface area of the white pines is comprised of 89.5% lateral roots and 10.5% tap roots when grown in 1 liter containers. The hard pines had slightly more lateral root surface area (91.5%). There were significant differences among provenances of *P. chiapensis* in lateral root area/shoot height. The high elevation sources, Barillas and San Gabriel, grew more slowly than the low elevation populations of Tutla and Nopoala but possessed greater lateral root area when assessed at 25 cm shoot height. No significant provenance differences were found in lateral root area/shoot height for *P. ayacahuite* (Table 2). Significant family differences were found for both *P. chiapensis* and *P. ayacahuite* for lateral root area/shoot height, number of lateral roots and lateral root length/shoot height but not for root/shoot ratios (Table 3).

Table 2. Provenances means of lateral root area (mm^2)/shoot height (mm) and their standard errors for *Pinus ayacahuite* and *P. chiapensis*.[1]

Pinus ayacahuite			*Pinus chiapensis*		
Provenance	Mean	St. Error	Provenance	Mean	St. Error
Ixtlan	21.04	.90	Barillas	22.43	1.02
Las Trancas	20.81	.73	San Gabriel	22.32	.96
Ocotopeque	17.87	.83	Nopoala	14.48	.58
			Tutla	15.53	.70

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[1] The values in the table are read as follows: Ixtlan, (for example) required 21.04 mm^2 of lateral root surface area to support 1 mm of shoot height.

Table 3. Summary of analyses of variance for the traits of lateral root area/shoot height (LRA/SH), length of the 5 longest laterals/shoot height (LL/SH), number of laterals (NLAT), and root/shoot ratios (RSR).[2]

Pinus ayacahuite	LRA/SH	LL/SH	NLAT	RSR
Provenance	NS	NS	**	NS
Families	*	**	**	NS
Pinus chiapensis				
Provenance	**	NS	*	NS
Families	***	**	***	NS

[2] NS = not significant; *, ** and *** probability > F of .05, .01 and .001, respectively.

Pinus chiapensis and *P. ayacahuite* fibrous roots only accounted for 8% and 15% of the total root surface area, respectively, versus 23% and 32% for *P. tecunumanii* and *P. maximinoi*. Family variation in fibrous root percent is shown in Table 4.

Table 4: Family variation in fibrous root percent by species. The number of families (N) in each category are expressed as percents.

		Fibrous root percent				
Species	N	0-9%	10-19%	20-29%	30-39%	>40%
P. maximinoi	12	0	0	50	33	17
P. tecunumanii	14	7	21	36	36	0
P. ayacahuite	13	30	54	8	8	0
P. chiapensis	15	73	27	0	0	0

There appears to be sufficient genetic variation in the root morphology of *Pinus chiapensis* and *P. ayacahuite* to warrant selection and improvement by tree breeders. However, it is not known what degree of improvement will be necessary to obtain trees that will survive moderate droughts of several months. Based on the results of this study, it is apparent that shoot growth rate in the nursery is not necessarily a good indicator of lateral root development.

Development of better nursery techniques in association with tree improvement activities will be needed if more hardy P. chiapensis and P. ayacahuite seedlings are to be produced. Alternative nursery techniques may include the establishment of bareroot rather than containerized nurseries, root pruning, and extending the period of time white pine seedlings are grown in the nursery prior to field planting.

Even though some provenance variation in lateral root development was observed for P. chiapensis, it appears that the greatest genetic gains will come from family and within family selection. Breeding priorities should emphasize improvement in the quantity of fibrous roots.

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GENETIC DIVERSITY IN PINUS STROBUS

Results of Range-Wide Provenance Studies in Maryland, 1965-1990[1]

by John B. Genys[2]

FDC: 232.12: 174.7 Pinus strobus L.: (752)

Abstract. About one hundred different geographic sources of eastern white pine from Canada and the United States were studied for twenty-five years in three Maryland plantations. Results from this long-term study are discussed in respect to diversity in germination, seed coats, cotyledons, seed weights, terminal bud formation, leaf-lengths, foliage color, survival, heights, diameters, susceptibility to ozone and sulfur dioxide, white pine blister rust, white pine weevil, and cambial electric conductivity. Included are some data from plantations in other states and from outside the United States.

INTRODUCTION

Eastern white pine, Pinus strobus L., is one of the most important forest trees of southeastern Canada and eastern United States. Estimates suggest about fifteen million seedlings of P. strobus are planted yearly in the United States alone. Smaller plantings of this species are established in other countries in Europe and Asia.

Studies of genetic diversity in eastern white pine were started during the post-WW II era. The largest provenance experiments were established by the U.S. Forest Service, the Natural Resources Institute of the University of Maryland, and the Forestry Department of Michigan State University (Garrett et al. 1973, Genys et al. 1978, and Wright et al. 1978). The respective project leaders of these experiments were Drs. E. J. Shriner, J. B. Genys and J. W. Wright.

MATERIALS AND METHODS

This report is based on data from Maryland's experiment with more than one hundred different geographic sources of P. strobus in the nursery and in three research plantations during the period of 1965-1990. Also, some information is utilized from plantings of the same sources in Germany, New Zealand, Australia and other states in the United States (Genys et al. 1978).

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All individual experiments were arranged in four completely randomized blocks with studied sources represented by four-tree plots in each block; a total of sixteen trees of each studied source per experiment. The Maryland research plantations are in three physiographic regions: (1) CP (Coastal Plain) near Annapolis MD; (2) PP (Piedmont Plateau) near Frederick, MD; and AM (Appalachian Mountains) near Oakland, MD. Their respective elevations are 5 m, 150 m and 790 m, and average lengths of growing season--about 280, 200 and 140 days, respectively. On all sites, soil quality was average. Details on experimental design and study sites were outlined in previous respective publications (Genys et al. 1978, Genys 1987).

RESULTS

Germination, seed-coats,and cotyledons, seed weights

In the Maryland Forest Tree Nursery, 119 seed sources of *P. strobus* varied in their speed of germination (Genys 1968). Sources from low elevations in the northern range germinated sooner than those from high elevation in the north. The advance in seed-coat shedding was significantly correlated with the same factors as the speed of germination. Also, the higher the average numbers of cotyledons per seedling, the later the seed-coats were dropped (r = 0.75). Cotyledon numbers, counted for 16 sources, ranged from 8.1 to 9.8. Phenotypic 1000-seed weights from different provenances ranged from about 13 grams to 32 grams, and were inversely correlated with the northern latitude of the seed-source and with the age of mother trees (r = -0.58).

Time of setting terminal buds and secondary growth

One-year old trees varied in the date of terminal bud formation by 45 days (from September 24th to November 8th). The lateness of bud-set was inversely correlated with the latitude of the seed source (r = -0.77). Two-year old trees varied significantly in their tendency to resume secondary growth after original terminal buds were formed. In different sources, the number of trees with such secondary growth ranged from 4% (Minnesota) to 58% (Maryland), and was inversely correlated with the latitude of the seed source (r = -.38).

Leaf-length and foliage color

Needle lengths of 2-year old trees ranged from 5.5 cm (Minnesota) to 10.0 cm (North Carolina), and were inversely correlated with the latitude of the seed source (r = -0.65). Also, they were correlated with some other traits typical to southern provenances. Three grades were used to score the foliage color of 2-year old trees, and different sources of trees ranged from 1 = yellowish (Manitoba, Minnesota) to 3 = bluish-green (some sources from Ohio and some other states in the central range). Since the dark color was most common among the trees from the central range, this characteristic showed no correlation to the latitude of the seed source. Also, foliage color was studied among the 17-year old trees in "CP" and "PP" plantations in Maryland (Genys et al. 1978). Again, the largest numbers of trees with a dark green foliage came from various locations in the central range, including those from Prince Edward Island, Canada.

Survival rates

The 12-year-old trees with the poorest survival in the Coastal Plain were from northern Ontario (#74), Minnesota (#1 and #55) and Quebec (#774). The highest mortality in the Piedmont Plateau plantation was among the sources from Quebec (#774); and in the Appalachians among the trees from northern Ontario (#73), Quebec (#531), New Brunswick (#530 and #775) and Prince Edward Island (#773). Apparently, the most sources with poor survival were from various parts of the northern range.

At sixteen years the survival rates of different sources in the Coastal Plain ranged from 25% to 100%; in the Piedmont Plateau, from 38% to 100%. Again, the sources showing the poorest survival rates were from various locations in the northern range.

Heights

Heights were measured at various ages, 1-year, 2-year, 12-year and 16-year. The 12-year heights were measured in Maryland (3 plantations), Michigan (2), Maine, New York, Pennsylvania, Illinois (2), North Carolina, West Germany (2), New Zealand (2) and Australia. Some of these plantations included less than complete sets of sources. For each site, heights were expressed in percentages of plantation mean, and averages of these percentages from all plantations were calculated for each source (Genys et al. 1978). These particular height indices ranged from 53% (central Ontario) to 136% (Tennessee #673), meaning that the trees of the best source were more than twice as tall as trees of the poorest source. Among other populations which were 20% or more taller than average were those from southern Ontario (#77), Tennessee (#7), North Carolina (#84), and from planted parent trees of unknown origin in Virginia (#561).

At age 16, in Maryland's Coastal Plain (CP), heights ranged from 48% (Quebec #531) to 124% (Norfolk #77) of the plantation mean (Genys 1987). In addition to sources listed above, a source with outstanding height was #763 from Tennessee. In the Piedmont Plantation, heights ranged from 46% (Cochran, Canada) to 125% (North Carolina #84). Other sources with 120% or larger heights were from McKean County, Pennsylvania and from western counties in North Carolina (#9).

Diameters

Diameters at breast height (DBH) of 16-year old trees in the Coastal Plain and the Piedmont Plateau plantations were very significantly correlated with the 16-year heights ($r = 0.93$ and $r = 0.92$, respectively). However, diameters showed a broader range of variation than heights, ranging from 44% to 150% of plantation mean in "CP" and from 37% to 144% in "PP". In the "CP" plantation, five sources had diameters 30% or larger than plantation mean; in the "PP" plantation, there were six such sources (Genys 1987).

Diameters of 17-year old trees in the Appalachian Mountain plantation (AM) ranged from 37% (Cochrane, Canada #76) to 126% (Connecticut #594), and were correlated with 12-year heights ($r = 0.81$). In total, eight sources had 20% or larger diameters than the plantation mean (Bates 1989).

Susceptibility to Ozone and Sulfur Dioxide

In 1977, eight different types of *Pinus strobus* were subjected to increased levels of sulfur dioxide (0.45 ppm and 0.9 ppm), and to increased levels of ozone, 0.9 ppm and 1.8 ppm (Genys and Heggestad 1978). Among the studied sources, the most resistant to sulfur dioxide were trees from southern Ontario (#77), and the most susceptible to SO_2 was *P. strobus* cv. 'nana Kelsyi.' With respect to ozone, the most resistant was a 'Brigham clone,' and the most susceptible, *P. strobus* cv. 'pumila.'

The second joint research project by the University of Maryland and the USDA included 16 types of *P. strobus* (Genys and Heggestad 1983). The specimens were treated with 1.5 ppm of sulfur dioxide for six hours. The most resistant was *P. strobus* cv. 'fastigiata,' and the most susceptible, a source of trees from South Carolina (#66).

White pine blister rust and white pine weevil

Susceptibility of different sources of trees to *Cronartium ribicola* Fisch was studied in Germany (Genys et al. 1978). In the nursery, the most susceptible seedlings were from Garrett County, MD, and the least susceptible were from adjacent Allegany County, MD. In the research plantation in Nordhorn, susceptibility rates ranged from 0% to 8%. The most susceptible sources were from New Brunswick and West Virginia. In Reinhausen, numbers of injured trees ranged from 0% to 25%; and again the most injured source was from West Virginia.

Susceptibility of different sources of *Pinus strobus* to white pine blister rust, *Pissodes strobi* Peck, was studied in North Carolina, New York, and Pennsylvania. In New York, the individual sources that escaped injury came from Ontario, West Virginia, Maryland, Pennsylvania and Illinois. In Pennsylvania, sources that included less than 10% of attacked trees were from Wisconsin, Minnesota, Quebec, Vermont and Pennsylvania. In North Carolina, 0% to 100% of the trees were attacked. The four non-attacked sources were from Vermont (#585), West Virginia (#615 and 563), Maryland (#562) and Virginia (#5). Among the least attacked in all plantations was the source #563 from West Virginia.

Cambial electric conductivity

Cambial electrical conductivity by different *P. strobus* sources was studied with a Shigometer (Model #02-67) in the Maryland's Appalachian plantation in August 1987 (Bates 1989). Conductivity levels of 107 sources of 17-year old trees ranged from 6.4 to 11.8 kilohms. These values were inversely correlated with average diameters (r = -0.78) and with heights of 12-year old trees (r = -0.60), and were positively correlated with the latitude of the seed source (r = 0.36).

DISCUSSION

The information presented in this report qualifies as a broad guide on genetic diversity in *P. strobus*. For specific data on any discussed characteristics, it will be necessary to use the original references.

A valid conclusion is that P. strobus is a very variable species. Some sources have superior characteristics for production of wood and fiber. Also, some sources may be more resistant to various destructive agents such as ozone, sulfur dioxide, white pine weevil, etc.

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COEVOLUTION OF MEXICAN WHITE PINES AND THEIR DWARF MISTLETOE PARASITES

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FDC : 165.1: 442.1: 174.7 *Pinus ayacahuite* Ehren: 176.1 *Arceuthobium* Bieb.

SUMMARY

Six of the 39 taxa of North American dwarf mistletoes (*Arceuthobium*, Viscaceae) parasitize mainly *Pinus* subgenus *Strobus*. In addition, 10 others dwarf mistletoes sometimes attack these trees, but their primary hosts are other conifers. The dwarf mistletoes have been present in North America for more than 20 million years (mid-Miocene), so they have long coevolved with their coniferous hosts. The species that are essentially restricted to subgenus *Strobus* are of most interest from the standpoint of coevolution as they can provide clues to evolution and taxonomic status of their host trees. Here I discuss the three dwarf mistletoes that parasitize subgenus *Strobus* in Mexico. *Arceuthobium guatemalense* occurs on *Pinus ayacahuite* var. *ayacahuite* in Guatemala and southern Mexico (Chiapas and Oaxaca). It is not known within the range of *A. ayacahuite* var. *veitchii* in central Mexico or the recently described *P. novo-galaciana* in Jaliso. Also, it has not been found on *P. chiapensis*, although this tree sometimes grows near infected *P. ayacahuite* var. *ayacahuite*. *Arceuthobium blumeri* is common in the Sierra Madre Occidental in Chihuahua and Durango on the tree usually known as *P. ayacahuite* var. *brachyptera* (or *P. strobiformis* of some authorities). The same dwarf mistletoe occurs on Cerro Potosí, Neuvo León, on an unnamed pine that Martínez placed in the *P. reflexa*-*P. flexilis* alliance. The third species, *A. apachecum*, a common Arizona and New Mexico parasite of *P. strobiformis*, is known from only one locality in Mexico: the Sierra del Carmen in northern Coahuila. The taxonomy of Mexican white pines in relation to their differential parasitism by various taxa of *Arceuthobium* will be discussed.

Keywords: *Arceuthobium*, Evolution, Parasitism, Mexico, Taxonomy.

MEXICAN WHITE PINE PLANTINGS IN THE HIGHLANDS OF COLUMBIA

C. Lambeth, William Dvorak and Masatoshi Endo

FDC: 232.12: 174.7 Pinus chiapensis: 174.7 Pinus ayacahuite Ehren: (86)

Smurfit Carton de Colombia experience with the Mexican White Pines began with a single row planting of Pinus chiapensis in 1971. Because growth and form were acceptable the species has since been planted in three arboretums, eight formal studies and four pilot plantations at elevations between 1600 and 2600 meters elevation, 3 N latitude and 1900 to 2500 mm annual rainfall. More recently, studies of provenance and progeny have been planted for Pinus chiapensis and Pinus ayacahuite with seed collected by CAMCORE. Results of specific studies and general observations are reported.

Whereas most tropical pines now being planted in Colombia require only five or six months in the nursery. Pinus chiapensis needs seven to eight months. Nonetheless, this is less time than in other parts of the world where a year or more is needed.

Early stand development is generally slower than that of other species such as patula, tecunumanii, kesiya, and oocarpa pines. Trees exhibit a yellowish color until about three years of age. After that point, a rapid growth phase begins. Notable exceptions occur in areas of high rainfall (2500 mm) and deep loamy soils where growth can be quite rapid even in the first and second years. Side-by-side species trials are still too young to judge but there is no doubt that chiapensis does some rapid catching up once established and is considered to be one of the promising new commercial species for the future. Individual trees can reach 13 to 15 m at age five.

CAMCORE trials show differences among provenances and families within provenances for growth and quality. The most notable difference is the striking inferiority of the four seedlots received from Zimbabwe. They were much smaller by far than the 49 families collected from select mother trees in the native range in Mexico. In general, forking is the most serious stem deformation and there is a small percentage of foxtailing. Nonetheless, results to date show great promise for developing a land race for Colombia through seed production areas, seedling seed orchards or clonal seed orchards if suitable seed production can be obtained. Cone and/or seed production is a common problem with pines in Colombia, presumably due to a very mild and nearly seasonless climate. Without a strong dormant period, whether from dry weather or winter, there is usually little to no seed met.

Low specific gravity (.36) may result in unacceptably low cellulose yield for chemical pulp. On the other hand, chiapensis has a very uniform and white wood which may result in more even cooking and easier bleaching. The low density and light color may make it highly desireable for mechanical pulps.

IMPROVEMENT OF *PINUS MONTICOLA* FOR BRITISH COLUMBIA, CANADA

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FDC: 232.12: 443.2: 174.7 *Pinus monticola* Dougl.: 172.8 *Cronartium ribicola* J.C. Fisch.

SUMMARY

The joint program of Forestry Canada and the British Columbia Ministry of Forests to produce western white pine seedlings resistant to white pine blister rust is described and progress to 1990-01 is reported. 313 parents have been selected for testing for a coastal seed orchard and 167 more are selected for an interior-zone orchard. Screening against rust has begun for 98 of these parents, using open-pollinated seeds collected *in situ*. Seed orchards should be established between 1995 and 1997 for coastal and interior zones, respectively. Orchards will consist mainly of seedlings selected for specific rust defenses from more-resistant parents. Support research, to refine testing or advance delivery of well-adapted, rust-resistant, planting stock, is described.

INTRODUCTION

Western white pine, *Pinus monticola* D. Don, is native to British Columbia in two large, disjunt areas: one lying mainly west of the Coast mountain range summit to latitude 50° 40′N, the other lying along the western slopes of the Monashee-Shuswap-Cariboo Mountain ranges and east to the Rocky Mountain trench to latitude 53°N. These areas are commonly called the south-coastal, and the interior wet-belt, zones (hereafter called "coastal" and "interior" zones).

Early exploitation of western white pine by the white settlers was heavy; the species grew to 60 m tall and up to one m stump diameter; it could be used for high-quality finish purposes, such as doors, window sashes and furniture. This reflected in its high stumpage value, which often was some multiples of those of its associated species. A strong price difference exists still in the interior zone.

White pine blister rust (*Cronartium ribicola* J.C Fisch.) was introduced to the west on infected seedlings from France about 1910 (Boyce 1948) and spread rapidly through both regions, causing severe damage or mortality in existing coastal stands by the late 1920s and to interior stands by the mid 1930s. Regeneration of white pine into openings caused by logging or fire usually was prolific, but the rust killed or weakened most of it, so that its future as a commercially-valuable species seemed threatened by the mid-1940s. Canada duplicated U.S. efforts to control the rust silviculturally starting in the 1930s, then began a program of testing promising individuals for genetic resistance in the late 1940s (Porter 1960). This program was abandoned in 1960 when the scientist resigned.

The pressure to intensify forest management on a shrinking land base and the recognition that western white pine seemed more-highly resistant than its coniferous associates to some common root diseases, particularly *Phellinus weirii* (Murr.) Gilb., and the success of the programs to produce genetically-resistant seedlings in the U.S. (Bingham 1983), have led to increasing attempts to establish such plantations or to manage natural stands for white pine. The estimated annual requirement of rust-resistant seedlings is approximately five million seedlings, although the target keeps rising as the area delineated by root rots increases.

In 1983, a Memorandum of Understanding was signed between the Canadian Forestry Service (now Forestry Canada) and the British Columbia Ministry of Forests concerning development of western white pine with increased resistance to blister rust. This paper describes the aims and goals of our program, progress to date and describes some of the support research, or that being pursued as possible alternatives to conventional, proven, methods. Fuller details are presented by Hunt (1988).

EXPERIMENTAL METHODS

Base Population

A goal of 300 parent trees per zone (coastal and interior) meeting our criteria: rust-free in attacked stands 20-60 years old, cone-bearing, of acceptable stem form and growth relative to neighbours, was set on the assumption that one tree in six might give useful, genetically-based, resistance and that 50 widely-separated genotypes would be sufficient to provide broad genetical variability for other adaptive traits.

Rust Sources & Culture

Aeciospores are collected from several locations each spring, inoculated onto both a cultivated *Ribes* garden containing clones of several species, and natural groves. The infections are monitored and intensified during the uredial stages by wafting spores from infected to "clean" plants. Once the telial-horn stage is reached, usually in early September, infected leaves are picked from several sources and placed on screens of open mesh approximately 50 cm above the seedling tops in a controlled-environment room for spore casting and inoculation.

Rust Inoculation

Open-pollinated seeds are collected from the specific trees during good cone crops, randomised at the start of their second year into 9-tree row plots in 45-cell "container" blocks (5 families per block) and exposed to rust under cool (12-16°C) humid conditions. Fine droplets of distilled water are applied to the seedlings by portable electric misters. When spore cast reaches ca. 3000 per cm^2, the stock is moved away from the rust source and kept in similar temperature, humidity and moisture conditions until spore germination occurs. Light, to open stomata, is supplied during spore germination and penetration. Following that, stock is returned to a nursery until examination the following spring.

Selection of Seed-Orchard Stock

Our process follows that developed in Idaho and Oregon: seedlings are to be selected for specific defense mechanisms (see Table 1) from families displaying reduced rust susceptibility. Stock is examined up to five times after inoculation, at 8, 12 to 18, 24, 36 and 48 months. Spot numbers per seedling are recorded during the first two inspections, whereas rust development, or absence from previously-attacked seedlings, is assessed from

Table 1: Proposed features used to select families and seedlings for a rust-resistant seed orchard of *Pinus monticola*.

Hypothesized Resistance Type[1]	Selection Unit	Resistance Mechanism	Resistance "Line"
Multi-genic ("Horizontal")	Family	Reduced needle spots/m foliage	All
"	Family	Slow canker growth ("stem tolerance")	A
Single-gene ("Vertical")	Seedling	Early shedding of rust-spotted leaves	B
"	Seedling	Fungicidal short shoot reaction	C
"	Seedling	Rust halted via bark reaction	D

[1] Hoff, R.J., and McDonald, G.I., 1980: Improving rust-resistant strains of inland western white pine. USDA Forest Service Research Paper INT-245. 13 p.

the second through fifth inspections. Seedlings selected at the end of the process will be 6 years old; they will have been maintained in transplant beds since the start of their fourth year, so will be easy to move to the seed orchard. These selections may be augmented by scions collected from outstanding individuals containing known resistance mechanisms from the Idaho and Oregon programs. Seed orchards are the responsibility of the B.C. Ministry of Forests. We anticipate that the first seed orchard, for the coastal zone, will be established in 1995 and that for the interior will be planted about 2 years later. Useable seed crops should be obtainable approximately 6 years after establishment of each orchard.

Support Research

Studies are in progress to determine genetic variability in white pine at the regional (coastal vs. interior), provenance-in-region and individual levels, and second-year variability, by assessing seed (Meagher and El-Kassaby, this conference) nursery and field performance, as well as protein profiles and DNA variability using restriction-fragment-length polymorphisms (RFLP) (White, 1989a & b). Narrow and wide crossing is underway to test the inferences of low genetic variability among provenances or zones detected by Steinhoff et al. (1983) and Rehfeldt et al. (1984). Other studies are underway to assess genetic variation in the rust, using both RFLPs and inoculations of separate B.C. rust sources on common seedlots: a "rust races" test (Meagher 1990). The impact of root diseases on white pine provenances and competing species is under test on nine sites, while six more sites test common seed sources from Canada and the U.S. against the "local" rust and environment.

Other studies are focused on delivering genetically-improved stock. Drs. Stephen Ross and Joe Webber, B.C. Ministry of Forests, Victoria, are working to enhance early and consistent cone production (both seed and pollen) so that seed orchards will meet their targets regularly and economically. Cone and seed insects are being studied by Dr. Gordon Miller, Forestry Canada, Victoria. Dr. Martin Lapp, Plant Biotechnology Institute, National Research Council of Canada, Saskatoon, is developing techniques for the mass propagation of selected seedlings; success would permit delivery of planting stock containing a specified balance of defense mechanisms appropriate to each forest site.

PROGRESS TO 1990-01

Base Population, Rust Inoculation and Selection of Seed-Orchard Stock

Selection of parents is nearly complete for the coast (313 trees), including 15 clones from Washington-Oregon, but is only half complete for the interior (167 trees) including 22 clones from Idaho. Seeds of 135 coastal and 61 interior parents have been sown; 98 families (18,646 seedlings) have been inoculated with rust in three years, starting 1987, 1705 seedlings have been evaluated at 48 months and 407 of these are potential selections for the coastal seed orchard. 6166 seedlings will be examined for rust in the spring of 1990 and 6750 more were exposed to rust in 1989; they will be examined first in May of this year. Sowing in 1990 is to be reduced because of poor seed crops the last two years, but indications of a good cone crop this year are widespread.

Support Research

Assessment of plantations of Idaho seed source on coastal lands (e.g. Bower, 1987) support Rehfeldt et al.'s (1984) contention that western white pine is broadly adapted, but heavier spring frost damage was suffered by Idaho vs. local trees at one site in the southern interior (Meagher 1988) and a strong latitudinal trend in frost damage with seed source was found at another site (Hunt, unpub. data). A study of the effects of controlled freezing during the autumn on range-wide seed collections is under way at the University of British Columbia, Vancouver, to test for differences in timing and depth of fall frost resistance. Variability in white pine's chloroplast genome is reported by White (1989a & b).

Preliminary analysis of early results from the "rust races" test indicate that interior parents, even those screened in Idaho for rust resistance, are more susceptible to the coastal rust sources than are coastal parents (Meagher 1990). Assessment of rust impact on our field sites will start about 1992, prior to establishment of the first seed orchard. Variability in blister rust in British Columbia also is being studied by White, using RFLP techniques.

Protein chemistry of white pine is being studied by Dr. Ekramoddoullah (this conference) using sodium dodecyl sulphate-polyacrylamide gel electrophoresis (SDS-PAGE) techniques, following modification of protein-extraction procedures to minimise the amount of interfering substances.

Some plantlets produced by Dr. Lapp (Lapp and Malinek 1988) from single embryos have been planted in a root-diseased demonstration area and others in an area free of root disease. More are expected every year. Grafts have been made from individuals selected for disease resistance by collaborators in Idaho and Oregon. Depending on results from the various tests of white pine and rust variability, these may be incorporated into the seed orchards, or held for other studies.

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SURVIVAL AND GROWTH OF *PINUS GRIFFITHII* GENETIC TESTS IN TENNESSEE

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FDC: 232.12: 174.7 *Pinus griffithii*: (768)

SUMMARY

Genetic test plantations of blue pine, *Pinus griffithii*, were established in 1988 at three Tennessee locations. The studies were analyzed for survival and growth. Significant differences occurred among families in survival and growth at each location. Differences due to block effects were significant at only one location. Survival and height growth were probably affected by a severe drought, rather than cold winter temperatures. Families that had a high percentage of survival and exhibited good growth at each plantation came from a wide geographic spectrum.

Keywords: *Pinus griffithii*, blue pine, genetics, variability

INTRODUCTION

The Asiatic blue pine, *Pinus griffithii* McClel. (syn. *P. wallichiana* A. B. Jacks.) and the North American eastern white pine, *P. strobus* L., are two Haploxylon pine species that are sexually compatible, despite geographic isolation. The rapid growth of hybrids between these species (cf. Genys 1979, Kriebel and Dogra 1986) is of particular interest in North American regions where *P. strobus* is an important commercial species. Kriebel and Dogra (1986) reported that *P. strobus* X *griffithii* hybrids grew comparably with a majority of elite *P. strobus* families in a North American test planting, although the paternal blue pines were described as being below average trees. Hybridization of elite blue pines with elite eastern white pines may produce trees that would outgrow either parent. Blue pine also has other desirable characteristics: resistance to blister rust (cf. Genys 1979) and ozone (O_3) pollution (Genys and Heggestad 1978).

In Tennessee, tree improvement research has been conducted on eastern white pine for more than two decades. Superior genotypes for growth and SO_2 resistance have been selected (Thor and Gall 1978). The performance of blue pine hybrids merits investigation on the performance of different seed sources of Pinus griffithii in Tennessee to eventually determine genetically superior blue pine genotypes. Blue pine selections would then be integrated into the existing white pine breeding program. In addition to potential for growth improvement, hybridization between blue pine selections with Tennessee selections may produce trees that exhibit hybrid vigor and resistance to blister rust and SO_2 and O_3 air pollution.

EXPERIMENTAL MATERIALS AND METHODS

Seedlots from a IUFRO seed collection of Pinus griffithii (Kriebel 1976a) were obtained from Professor H. B. Kriebel in 1986 (Table 1). Following stratification, the seedlots were germinated in 1987, and the

Table 1. Origin of blue pine seedlots used in Tennessee plantings.

IUFRO no.(s)	Location code	Seed origin Country, district, locality	Seedlot bulked (B) or kept by individual tree (I)
6001	1.0	Afghanistan, (nonspecified)	B
6008	2.0	India, (nonspecified)	B
6009-6011	3.0	Nepal, Tistung, Makawanpur	I
6012	4.1	India, Kashmir, Kangan	I
6115-6125*	4.2	" , " , Liddar Valley	I
6019	5.1	India, Himachal Pradesh, Manali	I
6032	5.2	" , " " , Chamba	I
6033	5.3	" , " " , Sanjoal	I
6034	5.4	" , " " , Simla	I
6036-6045*	6.1	Pakistan, Hazara, Panjoul	I
6046-6055*	6.2	" , " , Malkandi	I
6114	6.3	" , " (Murree), nonspecified	B
6178-6186	6.4	" , " , Kund	I
6187-6196*	6.5	" , " , Kuzagzli	I
6197-6206	6.6	" , " , Sharan	I
6207-6216	6.7	" , " , Shogran	I
6217-6226*	6.8	" , " (Murree), Thandhiani	I
6126-6135	7.0	Pakistan, Gilgit, Naltar	I
6137-6146	8.0	Pakistan, Chitral, Bamburet	I
6147-6156	9.1	Pakistan, Dir, Kalkot	I
6157-6166	9.2	" , " , Kumrat	I
6169;6172	10.0	Pakistan, Swat, Ushu	I
6227-6234	11.1	Pakistan, Azad Kashmir, Dawaryan	I
6235-6244	11.2	" , " " , Dungian	I
6245-6254	11.3	" , " " , Kern	I
6256-6265	11.4	" , " " , Sharda	I
6266-6274*	11.5	" , " " , Tararkhal	I

*all seedlots were not included in tests resulting seedlings transplanted into Cone-tainers^R (115 cm^3) for growing until field planting. Three experimental plantations were established in Spring 1988 at various locations in Tennessee using 1-0 container stock. The planting conditions varied among locations. The Bledsoe State Forest (BSF) planting in central Tennessee was in a sandy loam soil of variable depth (parent material - sandstone). The second planting was at Standing Stone State Forest (SSF) in north-central Tennessee on a clay loam soil of variable depth (parent material - linestome) with exposed bedrock. A site on the Ames Plantation (AP) in western Tennessee was selected for the third study. The seedlings were planted in silt loam soil approximately 1.5 m thick over sandy coastal plains sediment. The SSF and AP plantings were on well drained sites, while the BSF planting was on a moderate to poorly drained site. A fourth plantation in eastern Tennessee was terminated in 1988 due to poor survival.

The large number of families, coupled with low seedling numbers in some families, influenced experimental design selection. An incomplete block design was chosen to allow for representation of the maximum number of families in each planting, while relatively reducing the total number of seedlings planted per family. For location BSF and SSF, 132 and 96 families, respectively, were arranged in incomplete blocks with block size = 12 and 3 replicate plots per family containing 10 seedlings/plot. Seedlings were spaced 1.8 m apart within rows, with 3 m between rows. The field design for the AP location differed only in plot size, containing 5 seedlings/plot. This design was generated via computer software TENNDES^R developed by John F. Schneider and William L. Sanders, Agricultural Experiment Station, The University of Tennessee.

The survival data utilized GLMM^C, developed by the Department of Statistics, Louisiana State University, to complete a recovery of interblock information analysis using mixed model methods (Henderson 1975). Prior to analysis, the percentage data were transformed to angle to enhance the assumptions appropriate to analysis of variance. A least squares analysis of variance was completed via PROC GLM^R in SAS^R for height growth. Second year survival data from the BSF and SSF plantations and first year survival data from the AP plantations were analyzed. Analyses of second year height growth measurements were made for each plantation.

RESULTS AND DISCUSSION

The anaylses for survival and second year height growth revealed significant differences among families at each plantation. Block effects were significant only at SSF, possibly reflecting the varibility in soil depth. Overall survival was greatest at BSF (47%), followed by SSF (45%) and AP (30%). High mortality in North American blue pine genetic tests is usually ascribed to lack of cold-hardiness (Kriebel 1976b, Genys 1979). In these plantations, however, the relatively low survival at all locations was probably due to severe drought conditions that existed in 1988 and the 3 preceding growing seasons. Winter conditions in 1988-9, however, were relatively mild in Tennessee and probably did not adversely affect plantation survival. The average maximum height attained by any family was similar at all plantations; BSF - 20.7 cm, SSF - 22.7 cm, and AP - 21.3 cm. Some families showed little growth since planting, despite favorable environmental conditions in 1989. It is unknown why seedlings from some of these families have not begun to grow, as they appeared to be reasonably healthy.

Survival means (not shown) for families from different geographic areas were inspected for general trends over all plantations. The Afghanistan (location code = 1.0) seedlings were planted only at BSF, where they exhibited good survival (83%) and moderate growth. In contrast, seedlings from the bulked Indian seedlot (2.0) showed poorer survival at BSF but better growth. Seedlings from Nepal (3.0) showed poor survival at all 3 locations. Survival of seedlings from other provenances were too variable among locations to clearly discern general trends. Similarly, geographic trends in height growth cannot be detected among locations. This variability was reflected by height and survival means of some families common to all locations. Survival means of 4 families from Pakistan, Hazara, Shogran (6.7) illustrate the variability that can be encountered. Seedlings from 6214 showed poor survival at all locations. Relatively high survival of seedlings from 6207 and 6211 occured at BSF and AP, but was reduced at SSF. Alternately, survival of seedlings from 6280 was good at BSF, moderate at SSF, and poor at AP. Although general trends in survival and height were often difficult to detect, some individual families performed similarly at different locations. Families 6009 and 6141 had low survival percentages, while families 6142 and 6261 had better survival regardless of location. Height growth of families 6011, 6032, and 6233 was approximately the same at all locations.

Inspection of family survival means (not shown) at each respective plantation showed no geographic trends, other than those mentioned above, and high variability within families from the same geographic area, e.g., Pakistan, Azad Kashmir, Kern (11.2). Families from a number of geographic areas had high survival, ca. 90%+, in addition to families with survival under 20%. Inspection of height means of families with good survival at each plantation revealed similar variability within geographic areas.

Although there were differences among families in height growth at age 2, it probably does not reflect the potential for growth in the future. Genys (1979) correlated second year growth with ten year growth of different blue pine seed sources and found no relationship. An additional consideration in this study is the effects of the 1988 drought on growth. Height differences among families probably reflect differences in drought tolerance and subsequent recovery rather than true growth potential.

CONCLUSIONS

Significant differences were detected among families in survival and height growth at each plantation. These differences are probably due to drought response rather than different levels of cold-hardiness. With few exceptions, geographic trends over all plantations and within plantations were not detected. Inspection of data on families common in each plantation shows that some families survive and grow similarly regardless of location, while others do not. Families that exhibit good growth and survival, at each respective plantation, are represented from a wide spectrum of geographic origins. Geographic patterns may emerge in the future, as normal winter conditions in Tennessee will screen families for cold-hardiness.

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GROWTH PHENOLOGY OF VARIOUS TREE MODULES IN PINUS KORAIENSIS S. ET Z. PLANTATION

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FDC: 181.8: 174.7 Pinus koraiensis Sieb. et Zucc.

SUMMARY

The growth pattern of bud-shoot-needle of isolated 15-year-old trees, and seasonal changes in litter-falls and fine root dry weights in the unthinned 28-year-old plantation were investigated to understand the growth phenology of Pinus koraiensis. Shoot growth was continued by 7th June when buds appeared, while current needle growth was by 19th July when the bud growth started. Most of the litter-falls occurred in October but many of them were fallen in July and August due to storms. Fine roots were produced mostly in autumn(1004kg/ha), and were dead during winter and spring.

Keywords: Growth phenology, Pinus koraiensis, shoot-bud-needle, fine root

INTRODUCTION

Pinus koraiensis Sieb. et Zucc. grows in Korea, in the Amur and Maritime provinces of Russia(Mirov 1967). P. koraiensis is known as a shade-tolerant tree at young stages, but gradually turns to be intolerant as it grows(Hyun 1969; Kim 1968). The trees start to bear cones at around 15-year-old, but do not produce the cones much until they are at about 30-year-old(Hyun 1969). Because of both its nuts and timbers, P. koraiensis is one of the major tree species that have been widely planted in Korea.

Architectural approach may be useful in evaluating not only ecological growth process such as competition, differentiation and growth strategies but also silvicultural treatments such as pruning, thinning(Halle et al. 1978). It was found that the architectural development of P. koraiensis conformed Rauh's architectural model(Halle et al. 1978). In order to interpret this architectural process quantitatively, however, it is necessary that the phenology of such growth modules as bud-shoot-needle or fine roots must be expressed quantitatively. The growth phenology of the modules may markedly influence the tree architecture.

The objective of this study was to examine quantitatively the phenology of growth modules in *P. koraiensis* plantations.

MATERIALS AND METHODS

Three of 15-year-old *Pinus koraiensis* trees growing alone were selected, and their diameter and length of buds, needle length, and diameter and length of shoots at each whorl were measured in Suwon plantations weekly from April 12 to November 10, 1988. Five of 50cm by 50cm nylon screens(0.5mm mesh) were placed in the unthinned plantation of 28-year-old *P. koraiensis* and litter-falls were collected monthly from October 1987 to October 1988.

The amounts of fine roots distributed in a 30cm top soil were estimated from thirty sample cores(2cm in diameter) sampled in the same unthinned plantation as litter-falls were collected. Core samples were collected bimonthly from October 1987 to October 1988. In this study the fine roots were defined as unlignified roots less than 3mm in diameter and their associated root tips. The distinction between living and dead roots was made on the basis of the method that McClaugherty *et al*.(1982) used in a 53-year-old red pine stand.

A decision matrix(Fig. 1) modified from the method described by McClaugherty *et al*.(1982) was used to estimate the total amount of fine root products.

		LIVE	
		Increase	Decrease
DEAD	Increase	$P= \Delta L + \Delta D$ $M= 0$ $C= 0$	$P= \Delta L + \Delta D$ $M= \Delta D$ or $(-\Delta L)$ $C=(-\Delta L)-\Delta D$
	Decrease	$P= \Delta L$ $M= 0$ $C=(-\Delta D)$	$P= 0$ $M=(-\Delta L)$ $C=(-\Delta L)+(-\Delta D)$

Figure 1: Decision matrix illustrating one method for estimating the production, mortality, and decomposition of fine roots. The appropriate quadrant was selected according to the direction of change in live(L) and dead(D) standing crop for the successive two samples. Production(P), mortality(M), and decomposition(C) were calculated from the successive biomass using the equations in a chosen quadrant.

RESULTS AND DISCUSSION

The overall seasonal pattern of module growth in the *Pinus koraiensis* tree was shown in Figure 2. Bud appeared on the top of shoot near 7th June in this study. It appeared at the end of shoot elongation and its expansion began with the cessation of needle elongation. Such phenomena may be controlled by innate developmental program of the tree(Kozlowski 1971), and such pattern may be efficient to allocation in limited nutrients for tree growth.

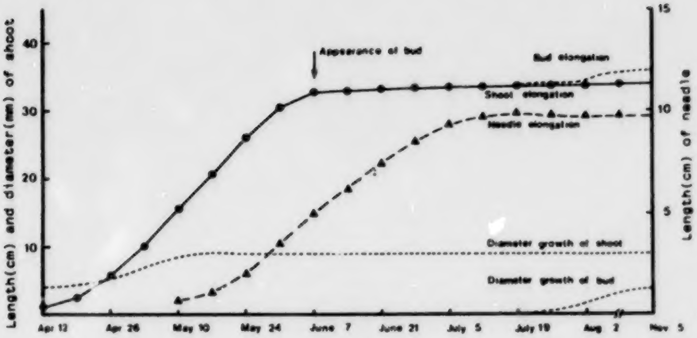

Figure 2: Growth pattern of module(bud-shoot-needle) of 15-year-old *Pinus koraiensis* trees growing alone.

Most of the litters were shed during October(Fig. 3). Many litters fallen in July and August in this study were caused by storms and this abnormal litter-fall was also reported by Gwak(1986) in *Quercus mongolica* stand.

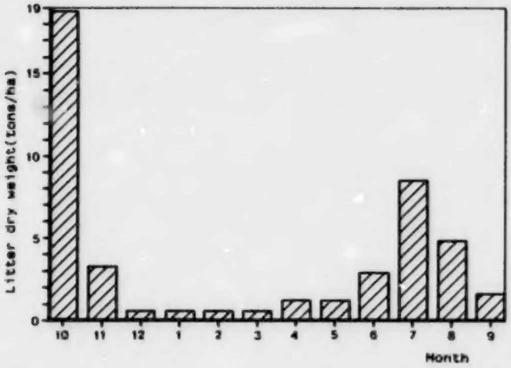

Figure 3: Seasonal changes of litter-fall in the 28-year-old *Pinus koraiensis* stand.

More living fine roots were found in autumn and early winter than dead ones,but in late winter, spring and summer, more dead fine roots were found than living ones(Fig. 4).

The results estimated from the decision matrix(Fig. 1) indicated that fine root biomass in the stand was produced mostly in autumn(1004kg/ha), most of them were dead during winter and spring(1914kg/ha) and decomposed mostly during summer(1398kg/ha)(Table 1). The decomposition rate might be dependent upon soil temperature(Fig. 4) as Swift *et al*.(1978) reported.

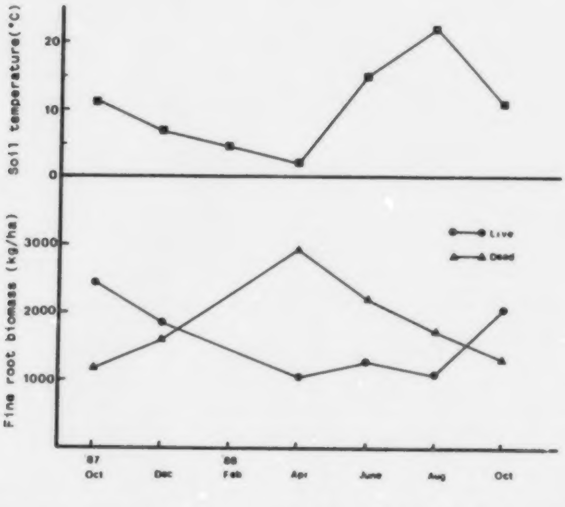

Figure 4: Seasonal changes of fine root dry weights(kg/ha) and soil temperature at 15cm depth in the 28-year-old *Pinus koraiensis* stand.

Table 1: Amounts(kg/ha) of seasonal production, mortality and decomposition of fine roots in the 28-year-old *Pinus koraiensis* stand

	Winter	Spring	Early summer	Late summer	Autumn	Total
Production	0	540	222	0	1004	1766
Mortality	583	1331	0	211	0	2125
Decomposition	155	0	721	677	421	1974

Various phenological events of growth modules of *P. koraiensis* are shown in Figure 5. Most of the module growth started in spring and early summer. Kramer and Kozlowski(1979) reported that much energy was demanded during those seasons. However, the amounts of current needles which are energy sources, were the smallest during those seasons since they have not fully expanded and most of the needles also have fallen in previous autumn. Therefore energy for tree growth was insufficient in spring and early summer. In late summer and autumn when litters had not fallen yet(Fig. 3) after current needles had grown up to old needles(Fig. 2), energy for growth was not lacking in module growth. Surplus energy in this season may be supplied for cambial growth of stem(Brand and Janas 1988) and for growth of fine roots(Table 1 and Figure 5), and may be reserved for winter and next spring(Kramer and Kozlowski 1979)

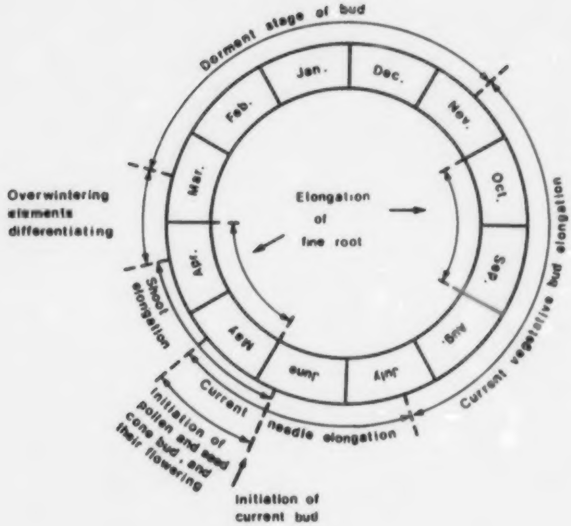
Dorment stage of bud
Jan.
Dec.
Nov.
Oct.
Sep.
Aug.
July
June
May
Apr.
Mar.
Feb.
Elongation of fine root
Overwintering elements differentiating
Shoot elongation
Current vegetative bud elongation
Current needle elongation
Initiation of pollen and seed cone bud, and their flowering
Initiation of current bud

Figure 5: Phenology of vegetative growth module, reproductive growth module, root growth module of *Pinus koraiensis* in Suwon, Korea.

CONCLUSION

Shoot growth was continued by 7th June while current needle was by 19th July. Bud appeared on the top of the shoot near 7th June when shoot elongation was ended, and its expansion began with the cessation of needle elongation.

Most of the litter-falls occurred in October but many of them were fallen in July and August due to storms.

Fine roots were produced mostly in autumn(1004kg/ha), most of them were dead during winter and spring(1914kg/ha), and decomposed mostly during summer(1398kg/ha).

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USE OF SOMACLONAL VARIATION TECHNIQUES TO PRODUCE RUST RESISTANT WHITE PINE

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FDC: 165.44: 443.2: 174.7 *Pinus strobus* L.: 172.8 *Cronartium ribicola* J.C. Fisch.

SUMMARY

Tissue culture techniques are being used in an attempt to recover somatic variation in eastern white pine embryo cultures. Plantlets with increased resistance to *Cronartium ribicola* as determined by *in vitro* inoculation with basidiospores will be multiplied clonally *in vitro*. Some of these plantlets will be rooted, and the seedlings will be screened for resistance in the greenhouse. Resistant seedlings will be clonally propagated for field evaluation.

Keywords: Blister rust, biotechnology, forest diseases

INTRODUCTION

Eastern white pine (*Pinus strobus* L.) was once the most valuable forest tree in the Lakes States. In 1889 more than 16.5 billion m^3 of white pine lumber were cut in Michigan, Wisconsin, and Minnesota (Betts 1954). During the next 20 years production dropped in half, and by 1932 only 467 million m^3 were cut nation-wide. Annual production through the 1950's averaged about 1.7 billion m^3. Today white pine plays only a minor role in the forest industry because of the lack of available growing stock. One reason this species is not being planted in greater amounts is white pine blister rust caused by *Cronartium ribicola* A. Fischer (Garrett 1985). Since it first appeared in the Lake States region around 1913, this fungus has been a major cause of mortality of eastern white pine throughout the region.

Efforts to find eastern white pine with resistance to blister rust began in 1937. Trees with apparent resistance were selected from stands severely affected by rust. Open-pollinated seedlings and grafts from these selected trees were exposed to the rust fungus. Although a high percentage of seedlings became infected with stem cankers, only a few of the grafted trees developed cankers (Riker et al. 1943). Work has continued on the production of rust resistant trees since Riker's early work, and seed orchards have been developed from many of the grafts of trees with putative resistance (Patton and Riker 1966, Ahlgren 1955, Heimburger 1962). Only a few of these trees, however, have shown the ability to confer rust resistance to their progeny at rates needed for production of rust resistant forest stands (Patton and Riker 1966). Thus, after 50 years we still do not have a proven, practical system that will produce large numbers of rust resistant seedlings for field planting. This problem remains one of the most critical obstacles to restoring eastern white pine as a major component of our Lakes States forests.

Our research group is investigating a different approach to solving the blister rust problem by using our tissue culture and pathology experience. The Forest Disease Project at the North Central Forest Experiment Station has a mission to develop more rapid systems for imparting disease resistance in forest trees. This program, which started about five years ago, uses the phenomenon of somaclonal variation to obtain genetic change without going through the long process of traditional sexual breeding. Somaclonal variation is the variation exhibited by plants grown in aseptic culture. Although the causes of somaclonal variation are not completely understood, the phenotypic and genetic variation found in various plant crops indicates that many factors are involved. These include minor point mutations, polyploidy, transposable elements, aneuploidy, and epigenetic changes. Somaclonal variation can be preexisting genetic variation that is expressed in regenerated plants, or it can be induced by the tissue culture process itself (Scowcroft and Larkin 1983).

We selected hybrid poplar for our initial research on somaclonal variation in a forest tree. Our objective was to produce resistance in these trees to Septoria canker caused by the fungus _Septoria_ _musiva_ Peck. Callus cultures of susceptible clones were initiated from stem internode explants taken from greenhouse plants. Callus cultures were maintained for 5 to 13 months before shoot proliferation was induced. Elongated shoots were excised and rooted before they were placed in the greenhouse. New, fully expanded leaves were collected from these plants and inoculated with conidia of _S. musiva_ on the abaxial surface. Plants with increased resistance to _Septoria_ were recovered from two of the three previously susceptible clones. Many regenerants were significantly more resistant to Septoria canker than their source plants (Ostry and Skilling 1988). These putative resistant plants have also been tested for field resistance for four years. Many of these plants continue to show strong resistance to Septoria canker. The best selections are now being asexually propagated for more extensive field evaluation.

Our research group has also used tissue culture of European larch (_Larix decidua_ Mill.) to produce trees with resistance to Scleroderris canker caused by the fungus _Gremmeniella_ _abietina_ (Lagerb.) Morelet. In this model system we use the cotyledon culture technique to produce somatic variants with resistance to _G. abietina_ (Diner et al. 1986). The plantlets are inoculated _in vitro_ with conidia of _G. abietina_. Those plantlets that survive three inoculations are multiplied both _in vitro_ and _ex vitro_ by means of axillary buds to produce large clonal lines of clones with putative resistance. At this time we have 100 clonal lines that are being multiplied for field testing.

We have recently developed a tissue culture system for screening European larch from different seed sources for resistance to Mycosphaerella laricina Hartig. By inoculating larch plantlets in vitro with the needlecast fungus, we have determined the relative susceptibility of larch seed lots within 6 months of seed germination. The results from these tests correlated very strongly with field evaluations of the same seed lots. The field evaluations, however, required 4 years to complete.

Using the knowledge we have acquired with Populus and Larix, we have recently started working on a system for producing blister rust resistant white pine. We are using an embryo culture technique with seed from putative resistant trees and from non-tested white pine from seed orchards. Currently we are producing large numbers of white pine plantlets from these seed sources. If our rates of somatic variation are similar to those we found in European larch, we should find 1-2 percent of these plantlets with increased resistance to blister rust. To identify these resistant plantlets, we must challenge them with the rust fungus. Standard procedures are to inoculate seedlings with rust basidiospores and to wait several months for symptom development to determine if the plant is resistant to the rust fungus. During this time any putatively resistant plants are losing their capacity to be regenerated asexually. To maintain the plants in a regenerative state, we are inoculating with basidiospores while the plantlets are in tissue culture. Some preliminary work on this type of system has been done by other investigators. Harvey and Grasham (1969), grew cambial explants of western white pine Pinus monticola Dougl. infected with C. ribicola. This was callus already infected with the rust and was not intended to serve as a challenge system. Diner et al. (1984) used callus from lines of Pinus lambertiana Dougl. that were both resistant and susceptible to C. ribicola in their challenge system. They observed a hypersensitive reaction on the resistant callus. Diner and Mott (1985) also inoculated plantlets of western white pine in vitro with vegetative hyphae of C. ribicola using intact needles and shoot apex wounds. They observed intercellular haustoria, characteristic of infection by basidiospores. They were not, however, attempting to determine resistance of the individual plantlets.

Our inoculation system, with basidospores applied directly to the intact plantlets, is closer to a natural system. However, because of the succulent needle epidermis of in vitro plantlets, we may be bypassing a resistance mechanism present in the epidermis. Thus our challenge system is conservative and we may not recognize an existing resistance mechanism in the epidermis. Based on other systems we have studied, we expect the in vitro basidiospore inoculation technique will produce visible infection symptoms in less time than ex vitro systems. Our in vitro Scleroderris inoculation system with European larch produced ratable results in 60 days versus 12 months under field conditions. Our basidiospore inoculations consist of multiple isolates of C. ribicola to avoid the possible problem of the existence of races of the fungus. Those plantlets with putative resistance will be subdivided in culture. A portion of each genotype will be screened under greenhouse conditions to verify their resistance before field evaluation. Subportions of these same genotypes will remain in tissue culture to supply the plants needed to develop clonal lines of the more promising material. Our strategy will be to develop rapid in vitro propagation methods that will retain clonal integrity and to use these techniques to produce large quantities of plants with resistance to C. ribicola.

The potential advantages of this system are both speed and the ability to produce large numbers of resistant genotypes. If the white pine project follows the pattern of the Populus and Larix studies, we should have our first rust resistant white pine plantlets this year. This in itself is not a great advance over existing grafted seed orchard material. However, if we can produce large quantities of resistant trees from many genotypes through the tissue culture process, we will have made a major advance on the problem that has resisted solution by forest tree breeders for the past 50 years. For the first time we might be able to establish multiclonal plantations of white pine with increased resistance to C. ribicola.

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VARIATION IN THE CHLOROPLAST GENOME OF PINUS MONTICOLA

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SUMMARY

FDC: 165.52: 174.7 Pinus monticola Douglas

The chloroplast genome of *Pinus monticola* was physically mapped. The genome lacks a large inverted repeat, and dispersed repeated sequences occur. These two structural features might be expected to confer a degree of variability on the genome that would prove useful in population studies. Restriction site variation in the genome of coastal and interior collections was surveyed for evidence of differentiation between geographically disjunct populations. The same variants occurred in both areas; however, the frequency of a variant genome was significantly higher in the interior than in coastal collections. The results indicate a difference in the pollen cloud of the two parts of the range. Chloroplast DNA is predominantly paternally inherited in *P. monticola*, though the presence of heteroplasmic individuals indicates occasional bi-parental inheritance (White 1989a,b).

Current studies on DNA variation in *Cronartium ribicola* and identification of non-host resistance genes in *P. monticola* using differential screening of cDNA libraries will be discussed.

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GENES RELATED TO MATURATION

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FDC: 161.4: 174.7 Larix laricina K. Koch

Phase change, or maturation in *Larix laricina* (larch) is associated with a number of morphological and physiological changes. These include changes in growth rate, growth habit, rootability and foliar characteristics. In addition, we have found that precociously flowering juvenile larch trees produce predominantly female flowers, whereas mature plants generally produce male flowers.

We have focussed much of our attention on the foliage of larch where a variety of phenotypic changes are associated with maturation. For example, needles from mature plants show increased levels of chlorophyll (both a and b), and increased levels of CO_2 fixation. These apparent changes in the photosynthetic machinery of the tree prompted us to investigate whether similar changes could be detected at the molecular genetic level. We have cloned and analyzed the structure and expression from the sequences encoding the small subunit of ribulose-1,5-bisphosphate carboxylase/oxygenase (*rbc*S) and the chlorophyll a/b-binding protein of photosystem II (*cab*). Both sequences are part of multigene families and are expressed in a light-dependent, tissue-specific manner similar to what has been reported in the angiosperms. The *rbc*S genomic sequences have a structure of two introns and three exons, with the position of the introns being identical to those of the angiosperms. The structure of the *cab* genomic sequences is currently under investigation.

Expression of the *cab* sequences in newly expanding foliage is relatively higher in juvenile plants than in mature plants. Later in the season the relationship reverses with *cab* expression being relatively higher in mature plants. This change in ratio appears to be primarily a decline in the level of *cab* mRNA in juvenile plants rather than an increase in expression in mature plants. The *rbc*S are similarly differentially expressed in newly expanding foliage with the levels of *rbc*S mRNA being higher in juvenile plants. Current data indicates that expression of all *rbc*S sequences declines as the season progresses.

We have also found that specific leaf weight is also changes with maturation. This has prompted us to begin an investigation into the expression of cell wall-related genes. The results of these studies will be reported.

INSECT AND DISEASE RESISTANCE GENES

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FDC: 443/444: 453: 165.3

The incorporation of current gene technology in woody plant pest and disease resistance studies has much to offer researchers. The time needed to develop resistant material using classical genetic methods can be shortened dramatically using molecular genetic techniques. Woody plants, as perenials, have a greater potential for resistance genes (R genes) in their genome. Many naturally occuring R genes may soon be identified as genetic mapping of woody plants progresses. Once genomes are understood, increased expression of these R genes is possible. Insect and disease problems that are now managed by external application of chemicals may be solved in the future by R gene insertion or increased expression of endogenous R genes. The decreased growth potential and product quality that pests and pathogens cause annually illustrate the need for stable resistance. Stable resistance genes can be subtle or radical in their interaction with pests and pathogens. Subtle R genes, such as proteinase inhibitors, are non-specific and reduce the growth and reproduction of the pest or pathogen. Radical R genes, such as the *B.t.* endotoxin gene, are pest specific and pesticidal in their mode of action. These radical/specific genes place selective pressure on the pest or pathogen. Whereas subtle/non-specific genes are less likely to be overcome by shifts in the population of the pest or pathogen. Many R genes are now or soon will be available. Examples include proteinase inhibitors and chitinases from plants, *B.t.* endotoxin from bacteria, and cecropins, lysozymes, and pheromones from insects. Single R genes can be more readily isolated and incorporated into woody plants by means of gene vectors. By incorporating a single foreign R gene into the diverse R gene containing genome of woody plants the possibility of a synergistic effect is greatly increased. Multiple R genes provide the best defense against pests and pathogens, but are difficult to isolate and incorporate. Therefore, the incorporation of more than one single R gene should be attempted to provide for more stable resistance. Wound-inducible promoters from potato and tomato proteinase inhibitor genes are activated by cell components (oligosaccharides) released during wounding. Systemic production of proteinase inhibitor mRNA has shown the promise of using wound-inducible promoters as regulators for other R gene constructs. Since research in molecular genetics is increasing dramatically, the prognosis of the successfull use of gene technology for increasing insect and disease resistance in woody plants is excellent. But, gene technology itself does not stand alone; it is a part of an ongoing forest genetics research program.

VARIATION AND POSSIBLE INTERACTION OF NUCLEAR AND CHLOROPLAST GENES IN FOREST CONIFERS

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FDC: 165.53: 174.7

The paper gives a summary of current research concerning variation of chloroplast and nuclear genes in forest conifers. Possible implications of these studies for elucidating interaction between chloroplast and nuclear genomes are also discussed.

The genes coding for the individual subunits of various chloroplast proteins are distributed between the chloroplast and nuclear genomes. Thus, synthesis of these proteins requires coordinated expression of the structural genes in both nucleus and chloroplast. Before embarking on detailed analysis of mechanisms of this coordination, it is important to obtain basic information about the variation and structure of the individual chloroplast and nuclear genes.

The chloroplast genome in conifers and some other gymnosperms has several unique features as compared to other plants. It is transmitted paternally, it lacks an inverted repeat region, and shows various gene rearrangements in individual species. Some genes coding for the chloroplast proteins often show inter-specific variation with respect to copy number, localization and structure. The observed variation is likely to have implications for the expression of these genes. Recent studies of nuclear genome in conifers gave first information about variation, localization and regulation of some ribosomal and protein genes. It appears that ribosomal genes occur in tandem arrays and show both inter- and intra-specific polymorphism in gene copy number. Two types of genes coding for chlorophyll *a/b*-binding proteins were found in *Pinus sylvestris*. In contrast to other plants, both genes are expressed not only in the light but also in the dark. Several other structural genes were recently isolated and characterized.

This information, along with rapidly accumulating knowledge about the chloroplast genes makes now possible comprehensive studies devoted to the interaction between chloroplast and nucleus. Taking into account often unique features of gene transmission, organization and expression in conifers, it is possible that the mechanisms of this interaction might have evolved in different manner than in other plants.

USE OF GENOME MAPPING IN CONIFER BREEDING PROGRAMS

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FDC: 165.3: 174.7

Genome mapping will be most likely be conducted for commercially important conifers for which advanced-generation pedigrees are available: loblolly pine, Douglas fir, Monterey pine, Scots pine and Norway spruce. Genome mapping using restriction-length polymorphisms (RFLPs) will provide a large number of new genetic markers which will be valuable for studies of conifer population genetics and evolution, for genetic identification of seed and pollen and for gene isolation and cloning. Most importantly, RFLP maps hold much promise for the identification of quantitative trait loci (QTL) and for RFLP-aided indirect selection. The value of these applications has yet to be established by theoretical and empirical studies.

THE ECOLOGY OF LEPIDOPTERA IN FORESTS SUFFERING FROM AIR POLLUTION.

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Air pollution influences herbivorous insect populations directly by intoxication and indirectly by means of host plant depression. The changes in ecological density of moths (the number of insects on 1 m^2 of leaves) along the gradient of pollutants are related to the mode of larval behaviour, the level of population density in the clean area as well as the level of pollution. In the area with extremely high pollution the maximum density of most lepidopteran groups is observed at certain distances from the source of pollution. If the pollution is moderate or low, the maximum density is observed near the source of pollution. The densities of some ecological groups of Lepidoptera (miners - Eriocraniidae, Gracillariidae, Coleophoridae etc., leafrollers - Tortricidae etc.) strictly correlate with the concentration of pollutants and can be used for bioindication. The spatial distribution of insects in areas of forest decline is influenced by changing such factors as the size of local populations, the distance between populations and the ecological preferences of moths. In extremely polluted areas the modification of microevolutionary processes in insect populations is observed.

POLLUTION INDUCED CHANGES IN FOREST-INSECT RELATIONSHIPS

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FDC: 181.45: 425.1: 425.3: 453

SUMMARY

Pollution will almost certainly lead to more simplified, and more volatile plant/insect interactions. These, in turn, could contribute to more frequent and widespread episodes of forest decline which are manifestations of complex system dysfunction: i.e. self-promoting cycles of ever increasing energy insufficiency among the dominant primary producers in an ecosystem.

INTRODUCTION

The effects of pollution on forest-insect relationships is extremely complex because of the many and varied ways that insects contribute to the structure and functioning of forest ecosystems. Insects are important primarily because of their role as consumers of primary production. The act of consuming plant biomass initiates a chain of interactions that cascade through the ecosystem. The process starts with reactions at the physiological level (eg. plant reactions to "injury", insect reactions to plant properties), which quickly translate to the ecological level (eg. plant-plant competition, insect reproduction, etc) and may eventually translate into evolutionary consequences. This chain of events which we observe at physiological and ecological levels is a direct consequence of the respective evolutionary histories of the interacting organisms, the insect and the plant. In other words, the crucial, early-stage interactions between insects and plants are in large part determined by each organism's physiological and ecological constraints. This means that the effects of pollution on forest-insect relationships will be predictable to the extent that we understand the manner in which plants and insects normally interact and the fundamental physiological and ecological constraints which underpin these interactions.

We will address this subject through the following steps: overview of forest-insect relationships, physiological/ecological constraints underpinning plant-insect interactions, predicting the effects of pollution on forest-insect relationships, and, reviewing the evidence.

OVERVIEW OF FOREST-INSECT RELATIONSHIPS

The role of primary consumers in terrestrial ecosystems has been reviewed in part by several authors in recent years (Mattson and Addy 1975, Crawley 1983, Smith 1986). In a capsule, insects affect system productivity and diversity through their effects on (a) plant growth and reproduction, (b) plant-plant competition, (c) rates of nutrient cycling, and (d) other members of the heterotrophic community.

Effects on Growth and Reproduction

Insects reduce individual plant growth and reproduction only when their "damage" exceeds the plant's ability to compensate for the particular injury (Chapin et al. 1987, Pearcy et al. 1987) This threshold level varies with the type and timing of the injury and the species and physiological condition of the plant (Mattson et al. 1988). For example, early-season leaf removal from woody plants is not as serious as equivalent midseason leaf removal when plants are creating energy stores for the dormant season (Waring 1987, Mattson et al. 1988). As a general rule of thumb, defoliations of less than 30% will not diminish plant production (Kulman 1971, Mattson and Addy 1975, Manion 1981, Belsky 1986, McNaughton 1986, Verkaar 1988, Maschinski and Whitam 1989).

Per plant compensatory responses to herbivory have to be integrated over the whole community of plants in order to understand ecosystem level responses to herbivory (Brown and Allen 1989). While some plants may suffer injury above their compensation threshold, others may not and furthermore may benefit from the reduced competition for light, and moisture. Indirectly, herbivory may enhance their ecological stature in the community. Responses to herbivory need to be integrated over substantial periods of time because of built-in time lags in system processes (Wickman 1980, 1986). This is especially true for assessing insect effects on reproduction because iteroparous woody plants may often produce flowers and seeds when environmental conditions for propagule establishment are highly improbable. Losses to insects under these circumstances have negligible impact on plant reproduction. But, such losses could have beneficial effects on plant growth if insects destroy the reproductive organs early enough in their development so that they cannot compete for carbon and nutrients with other growth processes (Mattson 1978).

Effects on Plant Competition and Succession

The course of plant-plant competition is highly subject to changes in trajectory depending on the environmental circumstances. The role of herbivores in this process is tremendously important but substantive evidence is lacking owing to the difficulty of carrying out rigorous, replicated experimentation (Crawley 1989). Never-the-less, there are numerous experiments that clearly demonstrate the potential that herbivores have to influence the course of plant competition and succession (Spurr and Barnes 1980, Crawley

1989, Louda et al. 1989). Other unequivocal evidence comes from natural events such as outbreaks of defoliators, and bark beetles which have undeniably accelerated community level changes, as in the case of the spruce budworm in eastern North America and the mountain pine beetle in western North America. In a similar manner, exotic insects have substantially altered ecosystem dynamics in North America: for example, gypsy moth in the eastern deciduous oak forests (Campbell and Sloan 1977), and the balsam woolly adelgid in Fraser fir forests (Witter and Ragenovich 1986).

Effects on Nutrient Cycling

Herbivores influence nutrient cycling through consumption of above- and below-ground plant biomass. The effects of detritivores/saprophages on accelerating nutrient cycling can hardly be doubted because of their important contributions to both the structure and metabolism of the soil/litter system (eg. pore space, comminution of organic debris, mixing of horizons, amelioration of pH, synergistic interactions with microorganisms, reservoirs for nutrients, etc). However, the effects of the above ground consumers are more difficult to verify. Above ground grazers usually increase the amount of macronutrients (N,P,K, carbohydrates, etc) that reach the soil/litter because they cause increased leaching from leaves, and premature litter fall that is high in these substances (Seastedt and Crossley 1984, Grace 1986, Risley and Crossley 1988). For the same reason they decrease the amount of fibrous, recalcitrant organic debris reaching the litter layer. Furthermore, herbivory tends to increase plant nutrient and carbon allocation to the foliage canopy which also tends to keep nutrients in the most easily mineralized plant tissue. The long term effects of above ground herbivory on nutrient cycling are significantly positive, although, in a single season the effect may seem insignificant. Above ground herbivory can also cause the local loss of nutrients (i.e. NO3) via stream export when defoliations increase above threshold damage levels (Swank et al. 1981).

Effects on the Second/Third Trophic Levels

Primary consumers, of course, are the vital link that allows "carnivores" or secondary consumers to exist in the otherwise indigestible world of plants. In this sense, then, primary consumers as a class are keystone species. That is, they are crucial elements that permit the establishment of a whole new trophic layer along with the complex ensuing interactions in an ecosystem. At a much smaller scale, certain primary consumers may be more synergistic than others in allowing the proliferation of other heterotrophs. For example, sucking insects (such as aphids, and scales) that produce prodigious volumes of honeydew, are keystone because their honeydew provides crucial energy sources for diverse organisms like epiphytic fungi, certain kinds of ants, bees, lepidopterans, predaceous wasps, and most importantly parasitic wasps, and flies (Mattson et al. 1989). In fact, Bentley (1977) proposed that the honeydew from sap feeders in temperate/boreal ecosystems may be the ecological equivalent of extra-floral nectaries in tropical systems.

PHYSIOLOGICAL AND ECOLOGICAL CONSTRAINTS UNDERPINNING HERBIVORY

Insect Constraints

Most phytophagous insects interact with only a few host plant species and do so in a consistent and relatively small window of time during each growing season (Mattson et al. 1982). Insect survival and growth therein depends on the balance between the plant's nutrients and non-nutrients, i.e. its allelochemicals. Each species of insect has a unique response curve to nutrients in their diets. Insects adapted to nutrient-poor tissues will have a response curve that reaches maximum at relatively low nutrient concentrations. On the other hand, insects adapted to nutrient-rich tissues will have the opposite response, asymptoting at relatively high nutrient levels (Mattson and Scriber 1987). Ability to cope with or tolerate allelochemicals will generally increase with dietary nutrient levels because insects will eat less when diets are rich, and thus suffer less exposure to noxious allelochemicals. Secondly, the insect's system for detoxifying xenobiotics may be fortified by the enrichment of its diet (Mattson and Haack 1987 a,b). Likewise, ability to cope with and survive the onslaughts of both macro- and micro-natural enemies will probably increase with diet quality because of faster developmental times that lead to lower exposure to enemies, and heightened immune and other defensive systems (Mattson and Haack 1987 a,b).

Efficacy of invertebrate parasites increases with the longevity of the adults. Longevity, in turn, depends on the quantity and quality of available nectar and or honeydew. Efficacy of vertebrate natural enemies declines as temperature rise because vertebrate energy needs decline and insect developmental rates increase.

Plant Constraints

Plant growth (i.e. cell division, and cell enlargement) usually responds positively to nitrogen availability until some upper response asymptote is attained. Tissue N levels are linked positively to growth, but often continue to increase (luxury uptake) even after growth no longer responds. Nutrient-stress adapted plants respond only weakly to nutrient changes, whereas nutrient-demanding plants respond strongly. Plant allelochemical content commonly varies inversely with plant growth because growth processes usually take precedence over differentiation processes (Lorio 1986, Lorio and Sommers 1986). In other words, factors that increase growth often, but not always, decrease allelochemical content, and vice versa. Exceptions can be the terpenoids and alkaloids whose biosynthesis does not have a simple either/or relationship with growth processes. As a general rule, plant vigor depends on having adequate energy to fuel the essential plant processes: growth, reproduction, defense, and respiration (Waring 1987, Loehle 1988). Very small plants (eg. seedlings) and very large plants (mature trees) are predisposed to catastrophic, positive feedback cycles of deteriorating energy insufficiency owing to small photosynthetic surface areas relative to whole plant respiration needs (Mueller-Dombois 1987, 1988, Osmond et al. 1987, Waring 1987, Loehle 1988, Harper 1989). Moreover, plant recruitment strategies can influence long-term plant success. Species that form vast monospecific cohorts of recruits, as can occur following fires or other disturbances, may be predisposed to extensive and simultaneous deterioration as they reach maturity owing to their inherent genetical and physiological homogeneity (Mueller-Dombois 1987). Such conditions are highly favorable for epidemics of pathogens and insects which may help to trigger the feedback cycles of deteriorating energy insufficiency, along with other stresses that build with age and size (Mattson et al. 1990).

PREDICTING POLLUTION EFFECTS ON FOREST-INSECT RELATIONSHIPS

The first key to predicting the effects of pollution on forest insects will be derived from understanding the effects of pollution on plant tissue quantity and quality which occurs during the insect's normal phenological window to its hosts. Tissue quality depends on the amount and balance of important nutrients and non-nutrients such as allelochemicals (Mattson and Scriber 1987). The host plant specialists, which feed on foliage, will largely respond to changes in plant nutrient availability. Other specialists which feed in stem phloem tissue, such as bark beetles and wood borers, will respond more to changes in plant defenses than tissue nutrient quality, per se (Mattson et al. 1988, Mattson and Haack 1987 a,b). However, tissue quantity can also be important in these cases because the ribbon of phloem/cambium under the bark must be thick enough to feed bark beetles and wood borers without causing serious competition (Haack and Slansky 1987, Popp et al. 1989).

The second key to predicting pollution effects on forest insects will be derived from understanding the direct and indirect effects of pollutants on ecosystem structure: plant species composition, and the competitors and natural enemies of the primary phytophages. Normally, insect-insect competition is not considered important in the structuring and population dynamics of phytophagous insects. However, Mattson et al. (1989) suggested that this may not always be the case. For example, aphids that were phenologically synchronized with the spruce budworm appeared to make the host plant less suitable for young budworm larvae through several possible undetermined mechanisms. And it goes without saying that rich diversities of natural enemies that can respond quickly to changes in phytophage populations are important in affecting the stability of the phytophage populations.

Following are five likely pollution scenarios.

Pollution Diminishes Plant Nutrient and Allelochemical Levels but Not Plant Growth

Ordinarily these changes will be detrimental to phytophagous insects, but not necessarily immediately. Insects compensate for dilutions of nutrients in their diets by increasing their consumption. If the dilutions are minor, then complete compensation by increasing consumption is feasible. However, if dilutions are substantial, then compensation by eating more will be incomplete, and development time will be protracted. These circumstances are usually detrimental, causing lower fecundity and higher mortality to natural enemies, leading to lower intrinsic rates of increase (Rmax). An exception to the above may occur if the stress increases the rate of nutrient flux in the phloem sap. Such being the case, aphids and other sappers may proliferate owing to increased availability of nutrients. Aphids are often parthenogenetic, have short generation times, and therefore have extremely high Rmax's.

Pollution Diminishes Plant Nutrient Levels and Plant Growth

Owing to reduced plant growth, there may be increased production of allelochemicals to exacerbate the problem of reduced nutrient concentrations for phytophages. This will likely lead to serious reductions in the quality of diet for which there is no simple physiological compensation. Consequently, the intrinsic rates of increase for most insects will decline substantially. Under these circumstance the only herbivores with relatively high quality diets will be those that tap into phloem tissue or phloem sap. The latter is very similar to cell cytoplasm, and is available to aphids and other such specialists without the normal diluting covering of cell walls, etc. This scenario, like the former one, will probably have long term, negative effects on forest-level nutrient cycling. In this case, lowered growth, increased allocation to allelochemicals (including lignin), will make the litter more recalcitrant and slower to mineralize (Chapin and McNaughton 1989). Thus the system will probably become less and less hospitable for primary consumers, and may convert through succession to nutrient-stress tolerant species.

Pollution Moderately Elevates Tissue Nutrient Levels

This circumstance will very likely enhance the physiological performance of insects. It will very likely also lower the efficacy of the phytophage natural enemies. Therefore, pollution stress that increases plant nutrient levels will effectively increase the potential intrinsic rate of increase (Rmax) of many phytophagous insects. This could very well lead to higher and more frequent oscillations of serious defoliation or other kinds of insect injury to plants that exceeds the plant's usual carrying capacity for the insect. On the other hand, increasing tissue nutrient levels may very well also increase the plant's capacity (Kp) for tolerating insect feeding. This means that the plants may have greater abilities to tolerate or compensate for injuries caused by phytophages. Very likely canopy development will be encouraged more than root development (Lechowicz 1987).

Chronic Pollution Substantially Elevates Tissue Nutrient Levels

Long term pollution that pushes tissue nutrient levels into and beyond the range of luxury consumption runs the risk of pushing plants into serious dysfunction: eg. crucial differentiation processes are jeopardized leading to poor lignification, inadequate cold-hardiness, low levels of dormant season energy reserves, etc. (Schulze 1989). Such plants may temporarily be highly suitable for insects because of their high nutrients, low allelochemicals, and protracted periods of susceptibility. Insect Rmax values may become so high as to make the insect/plant system highly unstable with episodic outbreaks the norm. At the very end, per plant carrying capacity (Kp) will become diminished owing to serious physiological dysfunction. Normal plant phenologies may be altered and so will normal nutrient balance. Eventually, nutrient-demanding plants may become the heirs of such environments.

Pollution Reduces Ecosystem Structure/Diversity

Pollution that is directly toxic or otherwise deleterious to the survival and reproduction of natural enemies of phytophages causes the latter's Rmax to rise. Likewise, high levels of pollutants that are toxic to plants that are important for sustaining phytophage natural enemies such as birds, small mammals, and parasites will also allow the intrinsic rate of increase of insects to rise. Increases in the ratio of host to non-host plants for the phytophagous insects can bring about concomitant increases in insect dispersal/host discovery success. All of this, of course, leads to higher Rmax for the phytophages.

REVIEWING THE EVIDENCE

Pollution Effects on Insects and Plant Tissue Quality

From exhaustive literature reviews, Hughes (1988), and Riemer and Whittaker (1989) concluded that insect and pollution levels are usually negatively correlated in areas of high pollution but positive correlated in areas of moderate to low pollution. Because almost all of these data came from observational rather than experimental studies, conclusions about cause and effect must be tentative. A small number of experimental studies have tended to confirm these general conclusions: the effect of pollutants on insect populations is complex and usually nonlinear, such that moderate levels favor insects whereas very high and very low levels do not (Fuhrer 1985, Hughes 1988, Reimer and Whittaker 1989). Few studies have actually explored the mechanism so the linkage to plant quality is as yet poorly understood. The strongest evidence comes from studies of aphids on pollution stressed plants which show very consistently that as stresses induce an increase in soluble proteins and amino acids, strong aphid population growth follows. Hughes (1988) concluded that ozone increases the foliar sugar levels of soybean which in turn increases feeding by the mexican bean beetle. Coleman and Jones (1988) found that ozone treated Populus stimulated feeding but not fecundity of the willow leaf beetle, thereby implying that foliar nutrient quality must have deteriorated and caused leaf beetles to compensate by eating more. Katoh et al. (1989) found that SO2 fumigation inhibited tannin synthesis in Japanese cedars, which in turn had higher levels of grazing by moth larvae. Riemer and Whittaker (1989) and Mattson and Haack (1987 a,b) reviewed the usual changes in tissue nutrients and allelochemicals when plants are subjected to pollution and drought stresses, respectively.

Effects on Ecosystem Structure

Tree species and individuals within a species vary considerably in their sensitivity to pollutants (Hughes 1988). Often, the most sensitive plants are the fastest growing species or individuals (Loehle 1988, Mueller-Dombois 1987). Consequently, pollution induces changes in forest composition by making the most sensitive plants less competitive and eventually more prone to pathogen and insect attack as has been observed in the San Bernardino Mountains of southern California (Miller et al 1963, Miller 1977) and elsewhere around the world (Mueller-Dombois 1987, 1988). Karnosky (1977, 1989) found wide variation in the sensitivity of aspen clones to ozone and SO2, thereby raising the specter of pollution-induced impoverishment of the aspen gene pool in more heavily polluted areas (Berrang et al. 1989). Chronic erosion of the natural genetic bases of plant species through pollution can have serious ramifications about their long term survivability in the face of other mounting stresses such as global warming and ever evolving pathogens and phytophagous insects.

If pollution stress commonly increases populations of sap feeding insects such as aphids and scales, it's likely that there will be a restructuring of the heterotrophic communities because of their keystone role as honeydew producing organisms. Organisms that benefit from the presence of honeydew will likely increase if other factors are not limiting them.

Although there are only few experimental studies that adequately test the predictions, most do in fact support them. The underlying theme of the predictions is that if pollution increases plant quality or decreases ecosystem complexity, it will very likely lead to less stability in plant/insect relationships. Aphids seem to provide unequivocal support for this hypothesis.

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INTERACTIONS BETWEEN GASEOUS AIR POLLUTANTS AND FOLIAR PATHOGENS OF TREES — A CRITICAL ASSESSMENT

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SUMMARY

A considerable body of knowledge exists concerning interactions between air pollutants and pathogens of agricultural crops. Very little research has been conducted dealing with such interactions on forest trees, especially mature trees. Most research that has been done contains several short-comings. Observations are often correlative in nature, do not deal with cause and effect, and do not utilize true controls. Pathogens may be misidentified or recent changes in taxonomy make it difficult or impossible to identify the pathogens as described previously. The nature and role of endophytes has not been fully explored. This paper points out areas in which research is needed and suggests how such research should be done.

BACKGROUND

It is well documented that forests are under stress from air pollution. For example, ozone is present in phytotoxic concentrations throughout eastern United States and in southern California. Sulfur dioxide continues to be a major problem around smelters and coal-fired power plants, especially in eastern Europe. Other phytotoxic pollutants, such as fluorides, chlorides, heavy metals, particulates, etc. occur near point sources worldwide. Concurrently, forests are attacked by a wide variety of pests and plant pathogens. Air pollutants may have a direct influence on the suscept plant, on the pathogen, or on various aspects of interactions between the two.

Ozone stress on forests is often regional in scope. Thus, interactions between ozone and pathogenic organisms are likewise regional, and may be difficult to ascertain without controlled experiments. In contrast, pollutant stress from point sources is of a gradient nature, with highest stress occurring adjacent to, and downwind from, the point source. Therefore, interactions between air pollutants and pathogens may be observed at various levels of pollution stress associated with distance from the source. However, observations in these situations are often correlative in nature and may bear no cause-effect relationships. In addition, there is often no attempt to distinguish among effects of multiple pollutants which may be present, such as phytotoxic heavy metals and sulfur dioxide.

AGRICULTURAL CROPS

As reviewed by Heagle (1973), Babich and Stotak (1974), Rist and Lorbeer (1981, 1985), and Manning and Feder (1980), considerable research has been conducted with air pollution-pathogen interactions on annual crop/pathogen systems. Agricultural systems are inherently easier to work with as compared to forest systems, for both spatial and temporal reasons. In general, facultative parasites of agricultural crops cause more damage on plants injured by air pollutants, whereas obligate parasites do less damage. There are, of course, exceptions to this generalization.

FOREST TREES

According to Smith (1981), tree pathogens that cause foliar diseases, as opposed to root and bole diseases, may be expected to be more highly influenced by air pollutants for three reasons: (1) these microbes may grow and develop vegetatively and reproductively in environments with relatively high levels of ambient pollutant concentrations (for example, leaf surface); (2) foliar tissue is known to be the site of primary accumulation of recalcitrant materials from the atmosphere, for example fluoride and heavy metals; and (3) foliar tissue is the primary site of direct damage to the plant occasioned by air pollution and leaf tissue may be expected to be predisposed to infection if physical or metabolic resistance mechanisms are adversely influenced.

Manning and Feder (1980), and Smith (1981) have reviewed portions of the literature dealing with interactions of tree pathogens and air pollutants. The purpose of this paper is not to review this literature again, but rather to suggest where additional research is needed. Three areas we would like to address are the use of correlative data, taxonomy of fungal species, and role of endophytes.

Correlations

In 1935 Koeck reported the lack of powdery mildew caused by Microsphaera alni on oak in the vicinity of a paper mill. Sulfur dioxide has been reported to reduce the incidence of foliar pathogens around smelters emitting heavy metals and sulfur dioxide (Linzon, 1958; Scheffer & Hedgecock, 1955). Grzywacz & Wazny (1973) found correlations between the concentration of industrial air pollutants and the incidence of certain foliar pathogens. Lophodermium pinastri was very common in polluted areas; other fungi were rare or represented by a single collection. Beven and Greenhalgh (1976) and Vick and Bevan (1976) correlated the incidence of Rhytisma acerinum induced tar spot on Acer pseudoplatanus with annual average concentrations of sulfur dioxide. However, such studies usually lack unfumigated check plants growing on the same sites and hence in the same microclimate. Correlations do not demonstrate cause and effect except possibly for saprophytic fungi that occur primarily on debris. Correlations do not indicate whether sulfur dioxide or metals are responsible for trends observed. Furthermore, correlative analyses done in one area may not agree with those done in other areas. For example, Tiarosporella parca is associated with a widespread needle blight of Picea sp. In Norway infected trees were associated with an industrial site with both nickel and sulfur dioxide emissions; in Switzerland, there was no correlation between fungal incidence and pollution emissions (Heiniger & Schmid 1990). Microclimate, host provenance, pathogen race, pollutant species and dosage, and other factors vary too much among locations to make generalizations. Correlations may reveal interesting trends but should not be interpreted as being related to cause and effect.

Taxonomy of Pathogens

Costonis & Sinclair (1972) reported Aureobasidium pullulans (="Pullularia"), associated with a needle blight of Pinus strobus, was isolated only from needle tissues killed by ozone, whereas the incidence of Lophodermium pinastri was unrelated to ozone fumigation. In contrast, Grzywacz & Wazny (1973) reported incidence of L. pinastri was greater in trees subjected to air pollutants than in trees on less exposed sites. However, L. pinastri has been since segregated into three species (Minter, et al., 1978), and over 40 genera of fungi now are known to grow in culture as "black yeasts", i.e., like "Pullularia spp." (De Hoog and Hermanides-Nijhof, 1977). Some of these black yeasts are asexual stages of needlecast fungi and needle blight fungi. Without voucher specimens, one cannot ascertain with which species these authors were working. Although different pullutant regimes were involved, one can speculate that Costonis and Sinclair were working with the pathogenic segregate L. seditiosum whereas Grzywacz and Wazny were working with the saprophytic segregate L. pinastri. Care must be paid to the taxonomy of the pathogen involved, and voucher specimens must be submitted for future reference.

Endophytes

There is mounting evidence for the widespread occurrence of fungal endophytes in conifer needles (Carroll and Carroll 1978). One of the common fungi associated with the loss of Norway spruce needles is Lophodermium piceae; evidence suggests that it is a non-pathogenic endophyte (Osorio and Stephen 1990). The benign nature of such fungi must be ascertained and their role, if any, in needle loss must firmly be established in air pollution-pathogen interaction studies. Again, correlations will not suffice. Along these same lines, Chiba & Tanaka (1968) found that Rhizosphaera kalkhoffii caused more damage and sporulated more profusely on pine needles fumigated with sulfur dioxide than on unfumigated needles. They concluded that the air pollutant facilitated the spread and development of the fungus which was already within the needles, rather than stimulating infection. Schulze (1989) suggested that, under the influence of stresses induced by pollutants, needle endophytes might become pathogenic earlier in the life of a needle. However, it seems likely that such fungi, which appear to sporulate only as needles begin to senesce, merely sporulate earlier because pollutant-stressed needles senesce earlier than normal.

Related Studies

Coleman et al., (1988) found no significant differences between the numbers of Marssonina leaf spots on untreated cottonwood leaves and those which had received an acute dose of ozone. In addition, treated leaves bore fewer Melampsora uredia than untreated leaves. In contrast to these studies, Weidensaul & Darling (1979) found that genetic differences within the Scots pine seed sources accounted for all of the variations in infection by Scirrhia acicola fumigated with both ozone and sulfur dioxide.

CONCLUSION

One may speculate that air pollutants may reduce the incidence of infection by obligate parasites, such as powdery mildews and rusts, and that facultative parasites may increase on trees stressed by air pollution. However, with the exception of a few studies, there is little evidence that observable interactions take place between air pollutants and foliar pathogens of trees.

RESEARCH NEEDS

There is need for more rigorous experimentation in order to ascertain if, indeed, air pollution/pathogen interactions do exist with forest trees. Studies to determine cause-effect, rather than correlational observations, are needed. Pathogens must be accurately described, correctly identified, and voucher specimens submitted. Pollutant species must be identified and characterized if field studies are conducted. And the role of endophytes must be explored.

A great deficiency in many studies has been the lack of a credible check, or indeed, any check. Disease incidence may be correlated with a pollutant gradient. However, this variation in disease incidence may be due to other factors, such as local microclimatic differences, that also vary with the pollutant gradient. One method of overcoming this problem is to establish open-top chambers along the pollutant gradient, and to maintain within such chambers rooted or grafted clones of both "resistant" and "susceptible" trees. These trees, grown in filtered air or exposed to ambient concentrations of local pollutants, singly or in combination, can then be compared with each other and also with the native vegetation. Koch's Postulates must then be completed with specific combinations of suscept, pathogen and pollutants under controlled conditions.

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ATMOSPHERIC POLLUTION AND FOREST PESTS IN EUROPE

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SUMMARY

The lecture gives a review of historical development of the air pollution situation in Europe since last century. It is demonstrated that air pollution has changed from easily recognizable smoke damage of trees near certain pollutant sources to a global problem threatening the forests in all of Europe. The state of knowledge and perspectives are discussed.

Keywords: Air pollution, forest insects, forest decline.

INTRODUCTION

European forests have been stressed for many years by environmental factors such as weather (storms, snow, ice, hail etc.), and insects, pathogens and anthropogenous impacts of tourism and improper forest management. More recently damage has been caused by smoke emissions. The air pollution problem began with the industrialization of Europe in the middle of the last century. This is when the industrial chimneys of the first big factories began to emit large amounts of smoke and dust. The rapid development of the European technical, power and chemical industries, and the increase of the automobile traffic together with human behaviour are the reasons for today's air pollution problems.

HISTORICAL REVIEW OF EUROPEAN AIR POLLUTION

In 1735 A. DARBY discovered a new technique for coke production, which was a prerequisit for iron and steel production, and in 1765 JAMES WATT invented the first powerful steam engine (Brockhaus 1972). These two important inventions signaled the beginning of a new era. The use of coke aided the development of an efficient iron and steel industry and the steam engine was used as an all-round steam power plant. This led to enormous growth in many industries and seriously impacted air quality. Smoke and dust from steelworks and industrial furnaces in the 19th century caused serious air pollution in industrial regions (Hasel 1985).

In 1866 W. SIEMENS and C. WHEATSTONE constructed, independently of each other, the first electrical generators (Brockhaus 1972). The ability to produce electricity enabled many further inventions such as the electric light bulb and the tramway.

Early in the 20th century electric lights replaced gasligths, and during World War I electricity replaced steam as the power source for factories. Special power plants were erected and continued development has led to the modern power stations of today. The use of sulphurous fuels in power stations became one of the most significant sources of air pollution. Sulphur dioxide is the most important emission compound in Europe and 56 per cent of the yearly SO_2 emitted originates from power stations in southern Germany (anonymous 1984). Nitric oxides, coal dust and chlorine compounds released by incinerators leads to further air pollution from power stations.

The first phase of industrialization in central Europe was characterized -as already said- by the development of a strong iron and steel industry. The first reports of forests heavily damaged by smoke appeared already in the middle of the last century in Saxony (Germany), close to industrial centers. Most damage was caused by steelworks and lead smelters and led, in 1860, to the first legal proceedings concerning air pollution injury (Hess-Beck 1930).

Initially smoke-damaged forests occurred in the neighborhood of the emittants where smoke and metallic oxides from steelworks had injured the trees. The trees exhibited yellow discoloration of needles and leaves, growth reduction, frequently malformation, and where extremely high pollutant concentrations existed high tree mortality occurred. Wind dispersal of pollutants was soon recognized and with industrial expansion air pollution and tree damage increased. Already by the second half of the 19th century the literature reported about first smoke-damaged forests in Saxony, in the Harz-Mountains and in the Upper Silesia coal mining areas. In Saxony a special smoke damage research station was established soon to investigate the phytotoxic effects of sulphur dioxide, which was recognized as the main pollutant (Hasel 1985).

The invention of gasoline and diesel engines at the end of the last century created an important and rapidly expanding automobile industry in industrial nations. After World War II the boom in the auto industry in Europe led to an enormous increase in traffic and to a change in the chemical composition of air pollution. More than 50 per cent of the organic compounds, and about 60 per cent of the nitric oxide and almost three-fourths of the carbon monoxide originate from internal combustion engines of motor vehicles.

As it is seen in the transparency house-heating and small commercial consumers contribute only 5 - 10 per cent of the total emissions (anonymous 1988). Before industrial companies installed effective smoke filtration plants, the chimneys were built taller, up to 600 feet or more, to better disperse pollutants in the air. However, this did not solve the problem of air pollution injury. It shifted the pollutants to longer distance and spread it over larger areas only. The result was a reduction in acute smoke-damage near factories and an increase in chronic long-term influence further from the source of emissions. In connection with the enormous increase of automobile traffic, the technical progress finally led to a global forest decline in Central Europe, which we recognize in the last twenty years. Prior to this time only the classic "smoke damages" were known in Europe. The wide-spread "forest decline", however, has only been observed since the beginning of the 1970s. Many different hypotheses have been developed to explain forest decline including extreme atmospheric conditions, improper forest management and other factors like fungi and noxious insects, but an essential factor appears to be the influence of acid rain (anonymous 1984), Bucher 1986, Courtois 1989).

Today it is undisputed that atmospheric pollutants, especially sulphur dioxide and nitric oxide, are the main factors involved in the European forest decline. In Central Europe, for example, sulphur dioxide emissions doubled from 1950 to 1972 (anonymous 1984).

On the other hand in northern European countries the forests appear to be relatively healthy, and the level of industrial pollution is low compared with the situation in Central Europe. However, the long-term accumulation of pollutants and their transportation over long distances may change the susceptibility of forest trees in insect attacks also in the north (Heliövaara and Väisänen 1988).

In reaction with ultraviolet light develope ozone and other photooxidants such as PAN (peroxiacetylnitrate), peroxides, aldehydes and organic acids, which have phytotoxic impacts on trees (Bucher 1986). This may explain why areas with relatively clean air such as the Black Forest, the Swiss Alps and Sweden sustain similar forest damage. Air pollutants together with site conditions, soil and climate result in a complex of impacts that weaken trees and increase their susceptibility to secondary attacks of insects and pathogens.

The first large scale inventory of forest decline was conducted in 1982. Fourteen European countries (including four communist countries) evaluated their forest damage by extensive investigations in 1986. Nine countries made inventories on all forest lands, and five restricted their inventories to certain regions. The results showed that the forests of middle Europe have been seriously impacted by atmospheric pollution. Five of the nine countries (Austria, Czechoslovakia, Switzerland, Federal Republic of Germany and the Netherlands) reported a level of injury between 35 and 60 per cent in 1986 (anonymous 1988).

The historical development of European forest decline showed us clearly that air pollution has changed from the easily recognizable smoke damage near certain pollutant sources as factories and metal smelters, to a global problem threatening forests in all of Europe. For this reason an international cooperation is essential.

Today new stringent laws require emission control standards for power stations, industrial companies and the motor vehicle industry. This is a first step in the right direction, however, the standards of different European nations are much too variable and slow to be enacted to have much effect in short time.

RELATIONSHIPS BETWEEN ATMOSPHERIC POLLUTION AND FAUNA

Air pollution can affect fauna in two different ways: either the animals can be directly handicaped or favoured by pollutants or indirectly influenced by weakened trees providing a more or less favourable breeding substrate for insect development. The direct influence of air pollution on animals may be illustrated with the following three examples. In Great Britain industrial melanism occurred with *Biston betularia* as it is shown in the transparency. The dark colored carbonaria-form occurred in only 1 per cent of the population in 1850, but today it occurs in almost 100 per cent of population in industrial districts (Vogel and Angermann 1976). Industrial melanism has also been observed in Europe in other Lepidoptera such as *Lymantria dispar* and *Lymantria monacha*.

At the beginning of this century a hitherto unknown honey bee mortality occurred. Further investigations showed it was caused by arsentrioxide (As_2O_3) emitted from an iron smelter near Freiberg in Saxony (Prell 1936). In the same area an inexplicable loss of hair , skin-melanism and skin defects occurred on red deers (Cervidae). These symptoms were also caused by the toxic influence of arsenic, which has been emitted from an iron smeltery near Freiberg in Saxony, transfered by wind to a forest 8 miles away (Prell 1936).

More important than such direct effects of pollutants on animals are the indirect influences on insect populations in consequence of the reduced vigor of the trees or the altered physiological conditions of the host trees. FÜHRER points out that forest insect outbreaks generally indicate the destabilization of forest ecosystems, which can have a variety of causes, although most involve anthropogenic influences. Site and weather conditions play a major role in triggering outbreaks of forest insects. But there is no doubt that air pollutions are able to change communities of herbivores and entomophagous organisms in forest ecosystems (Führer 1989). There are enough examples of insect outbreaks presumably caused by pollutants, but causalities are often unclear and difficult to understand (Heliövaara and Väisänen 1988). Our knowledge of the development of insect outbreaks in atmospheric polluted forests is still relatively limited.

The literature shows that several insect species find optimum conditions in smoke damaged forests. Publications by TEMPLIN (1962), BÖSENER (1969), SIERPINSKI (1984, 1985), FÜHRER (1983) and others demonstrate a number of insect species related to air pollution injury including needle, bud and young shoot feeders as well as bark and woodboring insects. The type of reaction depends on feeding behaviour of the insect species.

Table 1: Insects frequently occurring in smoke damaged forests (FÜHRER 1983)

PINE

Exoteleia dodecella
Rhyacionia buoliana
Evetria turionana
Petrova resinella
Phaenops cyanea
Acanthocinus aedilis
Criocephalus rusticus
Monochamus galloprovincialis
Pissodes piniphilus
Pissodes pini
Blastophagus piniperda
Blastophagus minor
Ips acuminatus
Ips sexdentatus
Pityogenes bidentatus
Xyloterus lineatus
Sirex juvencus

SPRUCE

Sacchiphantes viridis
Epinotia tedella
Laspeyresia pactolana
Pristiphora abietina
Pissodes harcyniae
Pissodes scabricollis
Hylurgops palliatus
Pityogenes chalcographus
Ips typographus
Xyloterus lineatus

FIR

Dreyfusia nordmannianae
Dreyfusia piceae
Cryphalus piceae
Pityophthorus pityographus
Xyloterus lineatus
Sirex juvencus

According to FÜHRER (1983) there are 17 insect species occurring on pine, 10 on spruce and 6 on fir that have been reached economic importance in smoke damaged areas (Table 1).

The species underlined in Table 1 have been most often found in forests influenced by smoke. Most of them are phytophagous insects feeding on needles, buds, shoots, bark or wood. Some Curculionids as Pissodes harcyniae and Pissodes scabricollis are even classical smoke damage insects of spruce trees and similar Blastophagus piniperda and B. minor on Pinus. Free feeding insects are represented only by spruce and fir aphids and by leaf wasps (Tentredinidae). At least in this example macrolepidopterans do not appear to be greatly affected. But BALTENSWEILER (1985) reported about an outbreak of the spruce-feeding type of Zeiraphera diniana in areas heavily polluted with sulphur dioxyde (SO_2). Also remarkable is the increase in wood boring insects (e.g. woodwasps, longhornbeetles and wood breeding bark beetles) in smoke-influenced forests.

On the other hand, TEMPLIN (1962) showed for the first time that primary forest insects such as Ips typographus, Blastophagus piniperda and Phaenops cyanea often occurred at lower population densities in smoke damaged forests than in less influenced areas.

HELIÖVAARA and VÄISÄNEN (1988) found that some species may increase in numbers and some others may drastically decline. Aphids, for example, are significant frequent near to pollutant sources, other insect pests seemed to be most abundant in the zone with a moderate pollution level, and were absent or scarce on both heavily and slightly polluted sites. It is concluded that atmospheric pollution can influences aphids indirectly via physiological changes in the host plants whereas direct effects of exposition to the pollutants are less important (Dohmen 1987). Also DONAUBAUER (1988) reported about higher densities of mites (Acari) in areas of forest decline, especially under influence of SO_2.

It appears there are no strong rules for insect attacks on polluted forests, because the susceptibility of trees depends on the degree of stress. This may explain existing disagreements in the literature.

Our hitherto knowledge of interrelationship between insects and smoke damaged trees bases on experiences from classical situations close to distingtive emissions sources, but little is known regarding interactions of insect pests and forest decline. We need more special investigations about interrelationship between insects and forest decline. In field studies, entomological investigations must be accompanied by measurements of air pollution, site influences, and by biochemical analyses of food (Führer 1989). Also we need more experiments with forest insects reared on polluted food, as HELIÖVAARA and VÄISÄNEN did, rearing pine sawflies and moths on pine needles collected from sample plots of polluted areas. They obtained smaller pupae (and consequently also smaller adults) and prolonged development on polluted food. Furthermore it has been found that heavy metal pollution influenced terrestrial invertebrates, including oligochaetes, isopods, chilopods and carabids (Heliövaara and Väisänen 1988).

FÜHRER (1989) evaluated the recent literature regarding forest decline and insects. He found that outbreak probability of forest insects and mites can be raised, lowered or left unchanged by air pollution impact. This depends on whether the altered chemical properties of the food plant satisfy or do not satisfy the specific requirements of the insects.

Today we know, insects do not play a causal role in the forest decline, however, trees stressed by pollutants are more susceptible to forest insect attacks and some pathogenes (Baltensweiler 1985). Under these circumstances secondary forest insects will become more important during forest decline in the future. The quality and concentration of emissions determines whether primary forest insects (such bark beetles as Ips typographus) or secondary species (such as Hylurgops palliatus and Trypodendron lineatum) will find suitable conditions for their development (Führer 1983).

In consequence of the European forest decline coniferous trees have a diminished number of needles. For this reason phytophagous insects feeding on the young or old shoots will become much more important on bad foliaged trees because of their reduced food quantity. Such insect species are Zeiraphera diniana feeding on spruce in eastern Europe, as well as Pristiphora abietina and Cephalcia abietis.

The larvae of Cephalcia abietis prefer the old needles of spruce trees. If the number of old needles is reduced as a consequence of air pollution, Cephalcia abietis has a more serious effect on such spruce stands. Under these circumstances the importance of Cephalcia abietis has increased greatly during the last few years. Outbreaks of this species associated with forest decline favour other secondary forest insects, and when 80 per cent of the needles are lost the spruce tree dies.

An other question is the influence of atmospheric pollution on the antagonists of the pest insects. Little informations exists on the toxicity of air pollutants and atmospheric depositions to predators, parasits and pathogens. The natural enemies of forest pests are, as everybody knows, most important mortality and regulatory factors of the population densities. Parasitoids and other predators seem to be more sensitive to air pollution and because of their great mobility have a higher risk of becoming contaminated by pollutants than phytophagous insects (Führer 1983). For this reason outbreaks of insect pests in air polluted regions can, in part, be triggered also by a lowered effectiveness of natural enemies (Templin 1962, Wentzel and Ohnesorge 1961).

All together, besides our classical pest insects the European forests will be increasingly confronted also with new forest pest problems in the near future, in consequence of altered conditions in insect-host relationships. Such hitherto well-balanced insect species which reached economically intolerable densities during the past twenty years are the sawfly Gilpinia pallida on pines in Austria, the pamphiliid Cephalcia falleni on spruce in Poland, the hemipteran Harpocera thoracica and Jassus lanio, and the beetles Agrilus sulcicollis and Xylotrechus antilope on oaks in Austria and Hungaria (Führer 1989).

Since forest conditions in Europe will not very much improve in the near future, the abundance of old and new forest pest insects will increase as a result of altered physiological conditions of many weakened trees.

CONCLUSIONS

The possibilities for effective control measures are small and we must concentrate our efforts mainly on the source of pollutants. There are already stronger laws for improvement of the air quality, but the limits vary too much within the different European countries. We need international laws and better international agreements, because atmospheric pollution is an international problem because of wind-drift of pollutants over national borders. But in contrast to America international agreements in Europe are much more difficult because there are many different Europeen languages and too many national and political restrictions.

The first step in this direction has been made by signing the Helsinki protocol in September 1987. 21 European nations agreed to reduce their sulfur dioxide emissions by at least 30 per cent from 1980 levels. But the thresholds of tolerance are still too high and too long term and no other international agreements have yet been made.

Together with legal actions we need intensive efforts to enhance the resistance of forest stands. Fertilization is one way to improve site conditions, and liming forest stands can counteract the influence of acid rain. If necessary further improvements can be made using magnesium or potassium.

Liming is common in European forests to compensate acid deposition in soils and will be positive for nutrition of the trees. However, liming leads to changes in the composition of the soil animal community. Generally, liming has a positive effect on groups of macrofauna as lumbricids, isopods, millipedes and probably also on molluscs, and furthermore on Nemathoda and Protura. Otherwise densities of most oribatid mites, certain collembolan and enchytraeid species, dipteras as well as some amoebae are found to be reduced by liming (Schaefer 1989). Dusty application of lime have been found to handicap small arthropods, such as ants, carabids and honey bees (Dustmann 1988, Schaefer 1989, Schmidt 1986, Wellenstein 1990).

Weakened trees show little resistance to insect attacks, because the defense mechanism of the trees are altered. As a consequence the mean density of endemic forest insect populations will rise. Under these circumstances monitoring of noxious insects and intensive forest management will be necessary. Dead and dying trees and the slash from logging operation must be removed and injured coniferous stands can be underplanted with broadleaf trees for improvement of their ecological conditions.

FÜHRER, who gave a very well-detailed review of the recent literature, made the following conclusions: "Forest protection in practise will be increasingly confronted with new pest problems; these will require appropriate strategies if they are to be overcome. Since increased pesticide application is not the appropriate response, the search for intelligent prevention techniques should have high priority in forest entomology. For this purpose, the assessment of the concrete risk of forest pest epidemics due to omnipresent near- and distant-source air pollution would be very helpful. This is hampered at present because the mechanisms operating in the pollutant-herbivore relationships are not yet understood in detail. This topic has high ecological and economical significance and deserves more attention in forest decline research than it has received in the past" (Führer 1989).

All measures suggested do not intend to change the European forests to smoke-enduring woods. The intention of all our efforts is to stabilize the forests and to increase their resistance in order to gain time until atmospheric pollution is reduced and a normal tree growth will be again possible in the future.

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EFFECTS OF AIR POLLUTION ON WILDLIFE: A SYNTHESIS

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SUMMARY

Air pollutants pose a threat to a variety of wildlife species. Known and potential effects are reviewed in this paper. Routes of exposure, toxicological effects, risks, biological monitoring and future research needs are discussed.

Keywords: air pollution, wildlife

INTRODUCTION

Air pollution legislation has focused increased attention on the effects of air emissions on wildlife. Effective management and protection of wildlife requires information on any aspect of their environment that can directly or indirectly impact their status and function in the ecosystem. Regulatory agencies and resource managers are also interested in the impacts of air pollution on wildlife because animals can provide early detection of airborne contaminants in the ecosystem, contribute to our knowledge of health effects, and assist in establishing emission standards.

HISTORY OF REPORTED EFFECTS

Since the end of the 19th century, more than 100 air pollution episodes involving domestic and free-living animals have been reported (Newman 1979). An example is the widespread loss of game animals in Germany caused by arsenic emissions. Between 60 to 70 percent of the red deer (Cervus elephus), roe deer (Capreolus capreolus), and wild rabbits (Oryctolagus cuniculus) died. The deer exhibited defective hair growth and antler formation, cirrhosis of the liver and spleen, and emaciation (Prell 1936). Even though the reporting of such incidents has increased there is a general paucity of information on effects on wildlife. The majority of wildlife incidents reported have involved game animals and small birds. These groups are not necessarily more sensitive but, like domestic species, are more likely to be monitored because of their economic importance and widespread public interest.

Prior to effective emission controls in the 1970's, air pollution incidents were primarily acute, large die-offs of wildlife caused by arsenic, fluoride, hydrogen sulfide, or asbestos. Other pollutants reported to cause damage to wildlife include cadmium, lead, zinc, oxidants, nitrogen oxides, sulfur dioxide, fly ash, and cement dust. The effects reported range from physiological, including death and injury, to ecological, such as behavioral changes. Incidents have been recorded in the United States, Canada, Czechoslovakia, Japan, England, Poland, India, Switzerland, Sweden and Yugoslavia (Newman and Schreiber 1985, 1988).

Recent air pollution events affecting wildlife have included both industrial accidents and chronic emissions. Release of radioactive materials, such as occurred at the Chernobyl reactor in the U.S.S.R., and the subsequent impact on wildlife represents another facet of the airborne contaminant issue. Release of pollutants from natural sources, such as volcanoes (e.g., Mount St. Helens) and trapped gases (e.g., the Lake Nyos incident) also emphasize the growing need for toxicology information.

EXPOSURE

Atmospheric contaminants come from a variety of industrial, agricultural, and forestry activities. The kinds and combinations of emissions can be classified into two categories: particulates and gaseous emissions. The behavior of these emissions in the environment is a function of the emission type, other associated emissions, the physical characteristics of the source, weather conditions, topography, and the nature of the vegetation surrounding the source. Therefore predicting the pathways of contamination and potential impacts and explaining observed impacts on wildlife requires an understanding of the physical and chemical behavior of these contaminants.

The routes of exposure of wildlife to air pollutants can be either direct (inhalation or dermal contact) or indirect (ingestion of contaminated food, loss of food resources, or habitat degradation). For any air emission incident, one or more pathways of contamination may be possible. A startling example of air pollution effects by inhalation was the death of 200 to 500 songbirds near a pulp mill in British Columbia, which resulted from high concentrations of hydrogen sulfide and other pollutants emitted to the atmosphere. The birds showed internal hemorrhaging in the lungs and liver (Harris 1971). With the exception of aerially applied pesticides there have been few reports of injury from dermal contact. Investigators in Czechoslovakia (Novakova, personal communication) have observed premature aging of the cornea in hares (Lepus europaeus) in areas with heavy sulfur dioxide emissions and particulate deposition from power plants and other industries. It was postulated that the hares living in these areas were exposed to heavy particulate deposits on the ground and on the vegetation.

Ingestion is the most commonly reported pathway of contamination for wildlife. Exposure can occur via surface contamination of food or hair by air emissions or through contaminated plant or animal tissues. For example, injury and death to wildlife from ingestion of contaminated food and water have been reported in rabbits and deer from arsenic emissions, in deer from fluoride emissions, and in sparrows from cadmium emissions (see Newman 1979, Newman and Schreiber 1985, 1988 for reviews).

TOXICOLOGICAL EFFECTS OF AIR POLLUTION

Although a variety of physiological and ecological effects of air pollutants in animals have been reported (Newman 1979), most information has come from controlled experiments that used laboratory and domestic animals to set standards. Sulfur dioxide is a common air pollutant and, in the laboratory, physiological changes have been observed at levels below ambient air quality standards. Mice, rabbits, and birds have been reported to be sensitive to these levels. Other pollutants, including hydrogen sulfide, photochemical oxidants, arsenic, cadmium, selenium, and lead have periodically been associated with wildlife damage and die-offs, but their toxicity to, and tolerance levels of wildlife species are mostly unknown.

Of the common air pollutants, fluoride's effects on wildlife have been most frequently studied. The symptoms of fluorosis observed are similar to those in domestic animals. Only recently, however, have there been attempts to evaluate fluoride's toxicity to wildlife in controlled studies.

Selenium is considered to be an air pollutant that will affect wildlife in the future. Because of known problems in domestic animals, both selenium deficiency and selenium poisoning are considered to pose health threats (Eisler 1985). Recent findings, such as those from the studies at Kesterson Reservoir in California, suggest a critical need for additional research on selenium. Cadmium levels in wildlife are also a concern. Recent studies have shown accumulations in game animal organs that exceed levels recommended for human consumption (e.g., Crete et al. 1989).

ACIDIC AIR POLLUTANTS

The effects of acidic air pollutants ("acid rain") on wildlife have been reviewed in several recent articles (Mitchell 1989, Newman and Schreiber 1985, Schreiber and Newman 1988). The acidification process, including interaction with the soil system and physicochemical changes in aquatic systems may directly affect organisms that are limited by such conditions, such as fish and soil fauna. For most species, however, acid rain is another indirect impact that may influence the homeostasis of individuals or populations. For example, when the acidity in snowmelt and spring runoff lower the pH of ephemeral forest ponds, the reproductive capacity in amphibians that depend on the ponds is reduced. Effects include embryonic mortalities and deformities, decreased egg masses, delayed development, and iono-regulatory failure (Freda 1986). Changes in amphibian populations can in turn have a number of ramifications since they are important predators and herbivores in ecosystems and provide a high quality food resource for a variety of wildlife.

Loss of aquatic species from acidified lakes, ponds, and wetlands also causes certain shifts in the predator-prey relations of a number of species. In Norway, it has been suggested that decreases in feral mink (Mustela vison) populations are a response to acid precipitation affecting fish, their primary food resource (Bevanger and Albu 1986). A recent study in Scotland also found significantly fewer signs of otters (Lutra lutra) in stretches of rivers where pH was low enough to be detrimental to fish populations (Mason and MacDonald 1988).

Acidification of ponds and lakes affects the availability of food organisms for wildlife and may also alter habitat that is used for cover and nesting sites (see review by Hansen, 1987). Reproductive success of birds with a diversity of feeding habits (divers, surface feeders, aerial flycatchers, piscivores, insectivores) can be adversely affected by acidification through impacts to their food resources (see reviews by Mitchell 1989, Goriup 1989). Acid rain and eggshell quality have been linked in studies in the Netherlands (Drent and Woldendorp 1989), Wales and Scotland (Omerod, et al. 1988) and Canada (Glooschenko, et al. 1986). It is suspected that calcium is less available in acidic habitats.

For some water birds, the interactions may be complicated by the competition with fish for a diminishing food resource (reviewed in Mitchell 1989, Schreiber and Newman 1988). Until acidity reduces or eliminates the fish, they compete with duck species for limited invertebrate prey. The negative effects of reduced densities of acid-sensitive prey may be partly offset by an increase in other aquatic prey when competing fish populations are reduced or eliminated.

Another indirect effect of acidification is the potential for increased bioavailability to toxic metals to wildlife. In regions remote from direct sources of contamination, higher levels of metals are being found in tissues of wildlife associated with acid-stressed as compared to non-acid-stressed habitats. Eggs of the common goldeneye (Bucephala clangula) collected from an acidified region of Sweden had high mercury concentrations when compared to nearby buffered lakes (Ericksson, et al. 1980). Similarly raccoons (Procyon lotor) from an acidified area of Ontario had liver mercury levels five times greater than those from a nonacidified area (Wren et al. 1980). Cadmium analysis of tissue samples from moose (Alces alces) and roe deer (Capreolus capreolus) collected in Sweden in areas remote from direct industrial pollution established an age-dependent increase in this metal (Frank, et al. 1981). In Scandinavia, eggshell impairment has been reported in songbirds that feed on aquatic invertebrates contaminated by aluminum mobilized under acid conditions (Nyholm 1981). Mercury levels in tissues of mink and otter (Lutra canadensis) from Ontario followed a pattern similar to that of fish and crayfish, indicating bioaccumulation through the aquatic food chain (Wren, et al. 1986). Wiener (1987), in a recent review, concluded that, although the mechanisms are poorly understood, surface water acidification may enhance the accumulation of methyl mercury, cadmium, and lead by fish in affected areas.

Recent research in Wales has demonstrated that the distribution of breeding dippers (Cinclus cinclus) is related to the abundance of stream macroinvertebrates, which in turn are shown to be reduced in acidic streams. Delayed clutch initiation, and significantly smaller clutch and brood sizes in dippers breeding along acidic streams as compared to breeding elsewhere were reported (Ormerod and Tyler 1987).

For terrestrial wildlife, the impact of acidification is most likely to be expressed through changes in soils and vegetation. For example, the distribution and abundance of salamanders may be influenced by soil pH (Wyman and Hawksley-Lescault 1987). Soil animals, such as earthworms and millipedes, have lower populations in acid soils (Altshuller and Linthurst 1983) and these changes could potentially affect bird species which use them as a food resource. These interactions are not currently well enough understood to permit assessment.

Acid precipitation and air pollution have been considered contributing factors in forest decline in Europe and North America (Cowling 1989). Any structural simplification of forest ecosystems that reduces the number of niches has an implied effect on the wildlife. Studies in Canada have shown the number of insectivorous birds living in the overstory were less abundant in dieback-affected maple stands (DesGranges, et al. 1987).

There is some evidence that the photosynthetic capability and nutritional value of vegetation may be influenced by airborne contaminants. In Poland, for example, a population of roe deer living in a pine forest affected by sulfur dioxide and particulate emissions exhibited a significant decline in the length, volume, weight, and trophy value of the antlers (Grodzinska et al. 1983).

RISK OF AIR POLLUTANTS TO WILDLIFE

Not all pollutants known to affect wildlife are regulated or regulated to levels that will prevent effects in wildlife. Currently, 15 pollutants are covered by the U.S. Clean Air Act and its amendments. These include nine "noncriteria" pollutants (asbestos, beryllium, mercury, vinyl chloride, fluoride, sulfuric acid mist, hydrogen sulfide, total reduced and reduced sulfur compounds) and six "criteria" pollutants (carbon dioxide, nitrogen dioxide, sulfur dioxide, particulate matter, ozone and lead). Twelve of these fifteen air pollutants have been associated with effects in wildlife (Newman and Schreiber 1988).

A review of animal effects studies reveals that biological effects can occur at and even below the promulgated standards (Newman and Schreiber 1988). For example, Light (1973) reported blindness in mountain sheep (_Ovis canadensis_) in the San Bernadino Mountains of California, a non-attainment area for ozone. Richkind (1979) observed genetic changes in deer mice (_Peromyscus_ spp.) in Los Angeles County, also a non-attainment area for ozone. High levels of lead have been found in rock doves (_Columba livia_) in urban areas that do meet the secondary ambient air quality standard for lead (Tansey and Roth 1970) and secondary lead exposure has been reported in a peregrine falcon (_Falco peregrinus_) preying on urban rock doves (DeMent et al. 1986).

Another possible air pollution risk to wildlife is the occasional accident or "upset" condition associated with emission sources. These "upsets" or episodic events may occur because of equipment malfunctions or meteorological conditions, or during start-up operations of industrial plants. In Alberta, the deaths of approximately 3000 migratory passerines was apparently related to an oil industry flare stack (Bjorge 1987). Other die-offs due to "blow outs" and venting in gas and oil fields have involved both birds (owls) and mammals (bats, moose, and antelope) (see review by Newman and Schreiber 1988).

Wildlife in Third World countries is considered to be particularly at risk from air pollution. As industrialization increases, both acute and chronic exposure to air pollutants are likely. In general, air pollution legislation and controls in these countries either do not exist or are not enforced. Costly pollution control equipment often is not feasible to install or practical to maintain under the prevailing economic and social conditions in less developed countries.

WILDLIFE AS BIOLOGICAL INDICATORS OF AIR EMISSIONS

Wildlife species have good potential as biological indicators of air pollution for several reasons: (1) they integrate all environmental conditions, both natural and man-made, in their responses, (2) they can show pathway points of accumulation and stress in natural and man-influenced ecosystems, and (3) they can be used as biological standards to verify the physical and chemical standards of air quality. Five wildlife groups were proposed by Newman (1975) as indicators of air pollution:

> Sentinel Species -- Highly sensitive wildlife species that show a quick and characteristic response to low concentrations of a given air pollutant. These species act as "early warning" species.

An example of a sentinel species is the bee. Bees are extremely sensitive to fluoride and sulfur dioxide. Fluoride concentrations in vegetation, that are not harmful to man, domestic animals or other species of wildlife, are lethal to bees.

> Bioassay Organisms -- Selected wildlife species whose ecology, physiology, and behavior are well known and whose specific and characteristic responses can be used to detect the presence of a particular pollutant, its concentration in the environment, or both.

In this group of organisms correlations can be established between a given pollutant, its ambient concentration, and the particular ecological or physiological response of these species. In Czechoslovakia, hares, pheasants, and ducks are being intensively studied for possible use as bioassay organisms as indicators of air pollutants.

> General Detectors -- Lesser known wildlife species that show a reasonably characteristic response to air toxics.

These species are wildlife groups whose response is indicative of air emission effects but not necessarily diagnostic, because of lack of information about the species or because of variability in the response of the species involved. For example, an European study (Newman and Novokava 1979) has linked a decline in the population density and geographic distribution of the house martin

(*Delichon urbica*) to air emissions. Because this response is also affected by factors such as weather and food supply, the diagnostic certainty is not sufficiently specific for the species to be used as bioassay species.

> *Thrivers* -- Wildlife whose presence or increased abundance indicates the occurrence of a particular air pollutant or an environmental condition associated with that pollutant.

Spruce forests affected by fluoride emissions have shown heavy infestations of spruce gall lice and bark beetles whereas contamination by sulfur and nitrogen dioxides have produced epidemics of sawflies.

> *Accumulators* -- Wildlife species that concentrate detectable quantities of a given air toxic in their tissues.

Common sites for accumulation of air pollutants are the blood, skeletal tissue, liver, lungs, hair, and other keratinous tissues. Long-lived and sedentary species make the best accumulator organisms. For example, femurs of deer have been used as standards for measuring fluoride contamination but even short-lived species such as small mammals have been used to monitor the distribution of airborne heavy metals.

FUTURE WORK

Newman and Schreiber (1988) identified a number of research needs pertaining to the impacts of air pollution on wildlife. Toxicological information on specific pollutants and methods of assessing risks to species and populations is a priority. Wildlife toxicology research using both laboratory and controlled field studies is needed to characterize responses to both acute and chronic exposures to most air pollutants. Species-specific information is lacking on acute and chronic toxicities of most air pollutants. Acute tests are needed to evaluate the consequences of industrial accidents when they occur, and to assess the potential risks to wildlife from proposed new sources. Chronic tests are needed to evaluate the effects of lifetime exposures of wildlife in the vicinity of point sources or in polluted regions such as nonattainment areas. Field testing that simulates natural environmental conditions is important.

Information on the relative tolerances of wildlife species is needed to determine what populations are at risk. Studies are also needed to evaluate the risks posed by various air pollution exposure routes. Inhalation studies in birds are particularly needed because of the high risk associated with such exposure and because of demonstrated sensitivity to various air pollutants. Based on reported incidents in gas and oil fields, hydrogen sulfide is a particular hazard to wildlife, and inhalation studies of its effects are especially needed.

Because most air pollution is a combination of various gaseous and particulate pollutants, toxicological research is needed to determine the antagonistic or synergistic effects of combinations of air pollutants. Air quality monitoring has shown that increasing amounts of organic pollutants, (e.g., benzopyrene) are being emitted into the atmosphere. The potential risk from such volatile organic compounds also should be investigated.

Wren (1986) summarized bioaccumulation and biomagnification data and the biomagnification potentials of a number of trace metals. Various environmental conditions can enhance or diminish these trace metals' bioavailability. More studies are needed on the influences of exposure patterns on the distribution of pollutants in tissues. For a number of pollutants, such as lead and mercury, air emissions represent one of several ways wildlife can become contaminated. Wildlife assessments should account for all potential sources of contamination and should be able to predict the resulting cumulative effects. A critical area of research is the relationship between air pollution effects and lower survivorship that results from debilitating injury and lowered resistance to disease or natural stresses.

The definitive challenge to scientists is to determine at what levels airborne contaminants exceed wildlife's natural capacity to accommodate variability.

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INFLUENCE OF IMMISSION DEPOSITION ON SOIL MICRO-ORGANISMS AS WELL AS ON ROOT AND STEM DISEASES

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SUMMARY

Immissions influence all organisms of an ecosystem in direct or indirect way. Despite many informations about effects on forest trees and microorganisms there are still gaps of knowledge regarding the interacting processes in a forest ecosystem under immission deposition. On basis of some examples the influence of pollutants on the fungal flora of soil, roots and stems of trees is discussed. It is evident that multidisciplinary research is needed urgently in future. Principally all processes in forest ecosystems under impact of air pollution are not separate events. They evolve and interact with each other under the prevailing environment.

Keywords: air pollution, soil microorganisms, mycorrhizas, root diseases, stem diseases

INTRODUCTION

During the past decades forest ecosystems were increasingly affected by both wet and dry depositions of anthropogenic pollution. Ecosystems are not adapted to this new abiotic environmental factor. Immissions consist of many different chemical components and vary in composition and concentration. This new factor is interacting with all other biotic and abiotic environmental factors. Therefore, correct assessments of the influence of immission depositions on terrestrial ecosystems or parts of them are highly complicated, particularly as ecosystems are composed not only of higher plants (e.g. trees, shrubs, herbs etc.), but also of a very diverse microflora (viruses, bacteria, fungi etc.) and microfauna (mites, collemboles, insects etc.) with numerous species. Also these parts of the whole ecosystem are influenced by immission components directly or indirectly.

Many publications are dealing with the impact of immissions on forest trees and their reactions in relation to morphological, anatomical, physiological, biochemical or genetical characters (see e.g. Smith 1981, Scholz et al. 1989, Schulze et al. 1989). Also informations are available about the influence of immissions on bacterial and fungal diseases of forest trees, reviewed by Heagle (1973), Laurence (1981), Horn (1985), Nevalainen and Liukkonen (1988), or Horn and de Kam (1988).

In relation to informations and observations on influences of immissions one has to distinguish between indirect effects on fungi living in soil or causing any disease of trees, direct effects, and interactions with various factors including the host tree. To date, in most cases the importance of the single factors are not very clear. Despite many separate informations published in the past years we are still far from an understanding of the processes in relation to influences of immission depositions on host-fungi-interactions in forest ecosystems. It is not possible to give here a complete review on all aspects of the topic. Therefore, the paper will be confined to a few selected examples on the influence of immissions on soil microorganisms, and on root and stem diseases, and will indicate the need of future research work on this field.

INFLUENCE ON SOIL MICROORGANISMS

Forest ecosystems are important sinks for dry as well as for wet depositions (Smith 1981, Fuhrer and Fuhrer-Fries 1982). The principal repository for contaminations is soil, which may be a particularly efficient short- and long-term sink. For many years it was assumed that forest soils have such a great buffering capacity that air pollutants would not cause acidification. But, nevertheless, over the past 20 to 30 years forest soils have undergone extreme acidification in various regions. In southern Sweden, for instance, the pH in soil has decreased 0.5 to 1 pH unit (Falkengren-Grerup 1987). The most important immission components for soil acidification are SO_2 and NO_x. Decreasing pH values cause an increase of aluminum ions in soil liquids, which is accompanied by a loss of nutrients (Falkengren-Grerup et al. 1987). High Al-concentrations in forest soils have been proved to have toxic effects on tree roots , and interact with the uptake of nutrient elements (Ulrich 1983, Rost--Siebert 1983). These changes occur particularly in the humus layer and less in the mineral soil. For more it is referred to e.g. Ulrich and Pankrath (1983), Matzner et al. (1985), Ulrich (1986) and Binkley et al. (1989).

Changes in pH, the concentration of aluminum and other toxic substances, or the nutrient element content of soil influence also the soil microflora (Smith 1981). In general, one can state (compare Hutchinson and Havas 1980, Smith 1981, Fuhrer and Fuhrer-Fries 1982) that decreasing pH causes a change from bacteria and actinomycetes to fungi, because the first ones have optimal development in neutral and alkaline conditions, while soil fungi can grow over a wide pH range. Decreasing pH will, however, influence the fungal flora in its composition, because some fungal species, populations or even strains are more tolerant to low pH values than others. And there is also different sensitivity to toxic soil substances as aluminum or heavy metals. In addition to important changes among dominant microbial groups also marked decreases can be found in decomposition of organic material, respiration, enzyme activity, N-mineralisation, nitrification, and N-fixation (Tamm 1976, Hutchinson 1980, Visser and Parkinson 1989). Regarding the adaptation of microbial flora to the new conditions in contaminated soils exact informations are still lacking. Hartman (1976) compared isolates of *Fusarium oxysporum* from soil at a smelter site in Montana and at a control site. The smelter populations were relatively tolerant to very high concentrations of copper, cadmium, zinc and lead. Genetical mechanisms like heterokaryosis, parasexuality or mutation in haploid hyphal cells and their propagation by uninuclear asexual conidia facilitate the selection of individuals with adaptation for new environmental conditions. In addition, Entry and Cromack (1987) found a high-elevation *Armillaria* isolate, which was only slightly affected by aluminum regardless of the pH value, when grown in pure culture.

Summarizing, one can state that changes of soil conditions by immission depositions result in quantitative as well as qualitative changes of the microbial soil flora. But most details of the microbial ecology, the microbial processes, the interactions between microbial populations of different species, between them and the higher plant populations, and the consequences of all changes and interactions for the whole forest ecosystem are not yet understood.

INFLUENCE ON MYCORRHIZAS

The fine roots of most forest trees are colonized by symbiotic soil fungi, which form mycorrhizal roots. Mycorrhizas are of great importance for trees in relation to nutrient availability, nutrient uptake, or effective protection against root parasitic microorganisms (Harley 1968). The fungus-host-interactions in mycorrhizal associations are highly specific and are controlled by complex cellular and genetical mechanisms (Gianinazzi-Pearson and Gianinazzi 1989). Therefore, it is evident that effects of pollution on plants or soil also influence such sensitive systems, directly or indirectly (Smith 1981). Trees damaged by dry or wet depositions show among others also pathological changes in the fine root system (e.g. Vincent 1989). In general, the fine root biomass is reduced. Low soil pH or content of toxic substances (aluminum, heavy metals) cause necrosis, anomalies and high mortality resulting in decrease of in a common occurrence of an ectendomycorrhizal form (Meyer

1984). In the latter case intracellular hyphae are common. The invasion is presumably caused by a general weakening of the host mycorrhizal roots, changes in mycorrhizal types, and sometimes tree.

Beside the indirect influence of immissions on mycorrhizas via weakened host trees also direct influences can be assumed by low pH values, pollutant gases (e.g. SO_2 or O_3) in large concentrations, high heavy metal and aluminum concentrations, and, last not least, a nitrogen input in form of high levels of nitrate and ammonium suppressing mycorrhiza formation. The response of mycorrhiza fungi to these factors varies between species and populations, and can cause changes of the mycorrhizal flora of a forest ecosystem. Nevertheless, it is rather difficult to solve details of such complicated interactions. Generalization of quantitative or qualitative changes is not yet possible as the forest ecosystems studied, the different sites and the environmental conditions can mostly not be compared.

Although many mycorrhizas do not produce fruiting bodies abundantly, changes in number or distribution of fruiting bodies of ectomycorrhizal fungal species, and changes in the composition of the mycorrhizal flora over a long observation period occur. In general, the number of species and the production of fruiting bodies is reduced in forest stands exposed to a high level of air pollution (Schlechte 1986). This is related also to a restricted mycelial growth of mycorrhiza fungi (Willenborg 1987). This fact has caused a dramatic impoverishment of mycorrhizal fungi in many areas over the past decades, and at least an endangering of several species (Benkert 1982, Winterhoff 1984, Arnolds et al. 1985).

INFLUENCE ON ROOT DISEASES

Tree roots and particularly the fine roots are injured by changes in the soil. Low pH or high aluminum content can be considered as preconditioning stress factors for damage or reduction of fine roots (Fiskesjö 1989, Fritz et al. 1989, Saastamoinen and Holopainen 1989, etc.). Under laboratory conditions abiotic stress factors caused an increasing susceptibility of Norway spruce seedlings for the soil-borne fungus *Phytophthora cactorum* (Lapin 1988). Under field conditions attack of fine roots of affected silver firs by a *Phytophthora* species was also shown (Blaschke 1982). On the other hand, the infection of roots of *Abies fraseri* seedlings by *Phytophthora cinnamomi* was inhibited by artificial acid rain with pH values below 4.0 (Bruck and Shafer 1983). Therefore, detailed informations about the conditions of investigations or observations are important.

Field studies were mostly related with the effects of gaseous pollutants (SO_2 and O_3) and less with the effects of immission depositions into the soil (Fuhrer and Fuhrer-Fries

1982). Therefore, it can not be decided in most cases, whether an increase of root diseases or differences of fungi involved in root diseases at different locations can be explained by influences of immissions. There are many reports on an increased occurrence of parasitic fungi in polluted areas compared to "unpolluted" ones (see the review by Horn 1985). In Polish studies the percentage of trees attacked by root and stem diseases has been assessed at various distances from a SO_2 source (Grzywacz and Wazny 1973). Although the total number of infected trees was generally low, the results demonstrate (1) different reactions of the fungi in relation to the SO_2 zone, and (2) different compositions of the respective fungal flora in the various SO_2 zones. There are also many reports on the occurrence of a larger number of parasitic and saprophytic fungal species on trees in industrial areas compared with unpolluted areas. Summarizing those informations one can state that the occurrence of *Armillaria mellea* and *Heterobasidion annosum* seems to be increased in polluted areas, although there are also contrary findings. Those tendencies depend on many factors and are influenced, for instance, by the vitality of the host, the tolerance of the fungal population, by competition, or by the concentrations of immission at the respective site. The present knowledge on those relations is very low. On one side we need studies about the interspecies and intraspecies variation of fungi against pollution components. And on the other side we need studies under controlled conditions about the infection process and the disease development under immission influences.

Experimental studies on the influence of pollution components are mostly dealing with agricultural fungal parasites (Heagle 1973, Laurence 1981). Studies on forest pathogens are scarce, on root fungi as well as on stem, needle and leaf inhabiting fungi. *In vitro* studies with root fungi exposed to different doses of pollutants (e.g. SO_2 and/or O_3) have shown generally, (1) differences in sensitivity between species (Grzywacz and Wazny 1973, Grzywacz 1976, Schnoewitz 1984, Stephan et al. 1985), (2) differences in sensitivity between strains (Schnoewitz 1984, Stephan et al. 1985), (3) decrease of growth rate, spore production, spore germination with increasing concentrations of pollutants (e.g. James et al. 1982, and papers mentioned above), (4) tolerance to concentrations of pollutants which were many times over those under field conditions, (5) different sensitivity of stages of fungal development (Grzywacz 1976, James et al. 1982). In studies with a range of different fungal species and strains, *Heterobasidion annosum* showed statistically significant differences between strains, but was in general less tolerant to SO_2 than an isolate of the soil-borne root pathogen *Cylindrocarpon* sp. (Schnoewitz 1984, Stephan et al. 1985). The tolerance of the latter one is interesting as *Cylindrocarpon destructans* was isolated frequently from roots of *Alnus incana* and other tree species grown in a Polish industrial area (Domanski and Kowalski 1987).

INFLUENCE ON STEM DISEASES

Stems, wood, branches, leafs and needles of trees are inhabited by numerous fungal species. Many of them live symptomless in sound looking tissues. Such fungi are called endophytes, and they attracted attention in the past years (e.g. Roll-Hansen and Roll-Hansen 1979, Kowalski and Lang 1984, Petrini and Fisher 1988, Carroll 1988, and others). The biology of most of them is still unknown, particularly in relation to conditions needed for the development of the life cycle. The development has probably something to do with a general weakening or senescence of a tree or parts of it. Then, the fungi appear, form fruiting bodies or can be isolated from diseased tissues. Often, such fungi are thought to be parasites causing the symptoms observed. The real cause is often unknown, and can be any biotic or abiotic environmental factor, and, of course, also the influence of air pollution. But as in the other examples mentioned earlier also the processes and interactions of stem diseases are not yet known in detail.

Under simulated acid rain conditions the fusiforme rust fungus *Cronartium quercuum f.sp. fusiforme* produced significantly fewer galls at rain with pH 2.4 than with pH 5.6 (Bruck and Shafer 1983). Also other stem and shoot infecting rust fungi showed a negative correlation between the incidence of the fungi and air pollution (Grzywacz and Wazny 1973, Linzon 1971). The results show that SO_2 and O_3 inhibit the development of rust fungi in the host tissue.

Some stem fungi of oak trees, as *Pezicula cinnamomea* or *Fusicoccum quercus* are probably stimulated by air pollution (Butin and Dohmen 1981, Flückiger et al. 1984), but the relation is not yet clear. In this connection one must mention that the recent oak decline in northern Germany is probably caused by climatic extremes and not by one of the many fungal species isolated from dying or dead oak trees (Balder 1989).

A severe die-back by *Gremmeniella abietina* occurred on Norway spruce in 1977 in southwestern Sweden (Barklund and Rowe 1981), an area most exposed to acid rain. In experiments with simulated acid rain *Gremmeniella* attack of Norway spruce was favoured, and simultaneously the occurrence of endophytic bark fungi was suppressed (Barklund and Unestam 1988). Germination of conidiospores was best in artificial acid rain of pH 3.5 and conidia survived even pH 2.8 for 24 hours (Barklund et al. 1983). High doses of SO_2 did not affect infection or disease development when the inoculum density was high (Laurence et al. 1984). Therefore, *Gremmeniella abietina* has probably an advantage to other endophytes in relation to the influence of immissions. Summarizing one can state that particularly fungi on above ground parts of trees are stimulated or inhibited by pollutants, and it is difficult to distinguish between primary (parasitic) or secondary (saprophytic) behaviour. We need a better knowledge on endophytes, their biology and their role for the host-fungus-interaction under impact of air pollution.

CONCLUSION AND NEED FOR FUTURE RESEARCH

It is a well documented fact that immission depositions affect microorganisms and diseases, directly or indirectly. These influences may have positive, negative or even additive effects. Many factors influence the reaction. It depends mainly on composition of immission, concentration, duration of exposure, diurnal or seasonal rhythm, climatic conditions, kind of forest ecosystem, and sensitivity of the respective fungus. Despite many results of investigations and observations there are still gaps of knowledge. More detailed research is needed on the effect of single or combined air pollution components under field and laboratory conditions, on the sensitivity of fungal species, populations or races to different concentrations, and particularly on the interactions with other microorganisms and with host plant populations. Only multidisciplinary research can solve these complex problems and must involve pathologists, physiologists, biochemists, geneticists, soil sientists and others. To date, results of most studies cannot be compared or generalized, because the conditions are unknown or quite different. Results are often controverse, although studies were conducted with the same tree species (but with different populations and/or age), with the same fungal species (but with different populations and/or races, and with different developmental stages), and under conditions which were considered to be similar (but had different environmental conditions, air pollution components, concentrations). Standardization is necessary, where possible, in relation to methods, plant and fungal material. Although many questions can be studied more easily in laboratories, open-top chambers or by simulation models, they will not replace exact field studies.

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VIRAL AND MYCOPLASMAL DISEASES OF TREES IN INDIA

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FDC: 444/449: (540)

Viral and mycoplasmal diseases are serious constraints in improving the production of trees in India. Fruit trees are affected most. Various diseases of citrus like tristeza, psorosis, exocortis, rubberywood and greening are major problems. Apart from these, minor viral diseases like vein enation, woody gall, infectious variegation, mosaic, impietratura, crinkly leaf leathery leaf etc. also affect citrus cultivation. Viral and mycoplasmal diseases have also been found to be very common in temperate fruit trees like apple, apricot, almond, cherry, peach, pear and plum. Very little information is available on the viruses and MLOs causing diseases in such tree crops. However, these diseases result in serious deterioration of the orchards of temperate fruits. In fig, mosaic disease is very common but its effect on the productivity of the fruit has not been studied in detail, Coconut and arecanut have serious diseases like root wilt, Tatipaca and yellow leaf. MLOs have been found to be associated with these diseases but the mycoplasmal etiology has not been fully confirmed. Papaya is a very common tropical fruit. Its production in the country is limited by viral diseases like mosaic, ringspot and leaf curl. Mulberry is infected with mosaic and yellow net vein diseases, both of which are of minor importance at present but can cause serious reduction in the growth of mulberry which is important for the silk industry.

Amongst forest trees, sandal is affected by a very serious disease known as spike disease which threatens the survival of this species. This disease has been shown to be caused by a MLO. MLOs have also been found to cause diseases in Eucalyptus and Ziziphus. Fortunately, many other forest trees in the country have not been affected seriously by viral and mycoplasmal diseases.

Among garden trees, frangipani is commonly found infected with frangipani mosaic tobamovirus. Inadvertant propagation of diseased plants has resulted in the spread of this disease in the country.

For the management of tree diseases it is essential that quick diagnostic procedures are developed and used so that the diseased plants are not used for further propagation. Chemotherapy has also been proved to be useful to some extent. This must be supported by appropriate health certification programme(s).

PARTIAL CHARACTERIZATION OF NEEDLE PROTEINS OF WESTERN WHITE PINE (*PINUS MONTICOLA* DON)

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FDC: 165.3: 174.7 *Pinus monticola* Dougl.: 172.8 *Cronartium ribicola* J.C. Fisch.

Western white pine (wwp) has significant commercial value and is resistant to laminated root-rot. Therefore, there is much interest in planting this species in British Columbia. However, wwp is susceptible to blister rust (Cronartium ribicola J.C. Fisch:Rabenh). To overcome this problem, a project has been established to obtain blister rust resistant pines. At present, trees are selected on the basis of morphological changes that occur following inoculation of seedlings with rust. This is tedious, time-consuming, expensive, and unreliable. A method based on biochemical markers such as the resistant gene(s) or their products (i.e. proteins) is needed . Moreover, the characterization of proteins associated with the resistance would aid in the genetic engineering of disease-resistant trees.

As an initial step towards this objective, work on the analysis of pine needle proteins was started. Needles (the site of blister rust infection) were used because needle proteins are likely to be involved in the host-pathogen interaction and some may be associated with disease resistance. Recently, a method of extracting needle proteins was developed. (Ekramoddoullah, 1989, Proc. of 3rd International IUFRO "Rusts Of Pine" working party conference, in press). Crude protein extracts of needles from mature trees contained glycine-rich proteins. Since such proteins have been implicated in plant defense mechanisms, I undertook to identify glycine-rich and other related proteins in pine needles. The proteins were separated by SDS-PAGE. Twenty-six proteins separated on the gel were quantitated by scanning the stained gel with a CCD camera interfaced with appropriate software (Bio Image). Analysis of needles from trees showed that the predominant protein component (32-39%) had a m.w. of 55 kDa and may represent the large subunit of the enzyme rubisco. The second most predominant protein component (14-25%) had a m.w. of 15 kDa. These two proteins constituted more than 50% of the total extractable needle proteins.

To identify glycine-rich proteins, needle proteins of a single tree was subjected to SDS-PAGE and electrophoretically transferred to an immobilon-P then stained with coomassie blue. 26 stained bands were cut out, hydrolysed, and their amino acid content analyzed. These analyses revealed that 27.5 kDa protein had the highest glycine content (13%). Considering the size and glycine content this protein may be chitinase. Another protein with an unusually high amount of proline (21%) and m.v. of 22.6 kDa was also identified. The significance of the findings is discussed in relation to the role of chitinase and hydroxy proline-rich extensin in plant-host interactions.

RESISTANCE RESPONSES IN SLASH PINE PROGENIES AFTER INOCULATION WITH *CRONARTIUM QUERCUUM* F. SP. *FUSIFORME*

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FDC: 232.11: 174.7 *Pinus elliottii* Engelm.: 443.2: 416.13: 411.16

Open-pollinated progeny from 106 slash pine trees in the USFS-Georgia Forestry Commission orchards were inoculated with basidiospores of *Cronartium quercuum* f. sp. *fusiforme* in five tests. Six to nine months after inoculation, the incidence of galls among the 106 families ranged from 3 to 77%. In the five tests a mass susceptible source averaged 70% of the seedlings with galls with a range of 62 - 75%. The mass susceptible source had more galls than 59 of the 106 families tested according to the 0.70 disease ratio computation (percent galls test family/percent galls mass susceptible = $\leq$ 0.70). The 0.70 disease ratio was more conservative than the T (LSD) test (67 families resistant), but less conservative than Tukey's (HSD) test (42 families resistant) in distinguishing susceptible and resistant families. Responses to infection differed in symptoms other than galls between resistant and susceptible family groups. Seedlings with no stem symptoms (either needle spots only or no symptoms) averaged 43% of the resistant family population but only 19% of the susceptible population. Seedlings with symnos (stem symptoms without swellings) averaged 25% and 14% respectively in the resistant and susceptible populations.

INTEGRATION OF GIS AND ECOSYSTEM PROCESS MODELS:
SITE-SPECIFIC MAPPING OF RUST HAZARD

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FDC: 443.2: 172.8 Cronartium ribicola J.C. Fisch: 180:585

White pine blister rust is a major problem in white pine forests of North America. Rust Hazard is conditioned by topographic, climatologic, and vegetational aspects of individual sites. Ecological and micro-climatological models could meld site-specific attributes into a hazard expectation for small geographic units (i.e., 0.5 hectare cells). Unit attributes of *Ribes* density, *Ribes* distribution pattern, stand basal area, white pine site index, leaf area index, precipitation isohyet, albedo, elevation, slope, aspect, east horizon, and west horizon would be needed to initialize existing models. A base weather station of known latitude, elevation, and annual precipitation record must supply daily maximum temperature, minimum temperature, and precipitation. Daily output from the climate model could simulate occurrence and duration of *Ribes* and pine infection periods. Annual estimated amount of rust infection, expressed as cankers/1 000 needles/year and averaged over 10 years, could be mapped by 0.5 hectare cells to provide information supporting integrated management of white pine blister rust. Remote sensing of topographic and vegetational data to initialize the models has potential to enable economical creation of blister rust hazard maps for stands, drainages, or larger management units. After appropriate calibration, the technique could supply maps depicting hazard to any pine rust.

These ideas were tested by creation of a blister rust hazard map for the Priest River Experimental Forest located in northern Idaho, USA. Remotely sensed topographic and vegetation data were obtained, placed in a GIS environment, and coupled to blister rust epidemic models. Mapped hazard was then compared to hazard previously determined on four small plantations.

CONIFER SHOOT BORERS: A REVIEW OF SOME MAJOR FOREST PESTS

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SUMMARY

Shoot boring insects in the genera _Eucosma_, _Pissodes_ and _Rhyacionia_ are important pests of conifers, particularly pines, in many parts of the world. Attacks by these pests are generally most serious during stand establishment and prior to crown closure. Damage consists of growth and/or form loss, decreased wood quality, increased rotation periods and, occasionally, death of heavily infested trees.

Damage is usually most common in open stands with sparse nonhost vegetation. Cultural practices such as intensive site preparation or release treatments that remove or decrease competing vegetation often increase pest populations and damage. Establishment of extensive areas of single-species plantations often exacerbates problems with shoot borers. Hosts growing on low quality sites, or sites to which they are poorly adapted, are often more susceptible to some lepidopterous shoot borers, particularly _Rhyacionia_ spp. In contrast, _Pissodes_ spp. tend to select the largest and apparently healthiest trees within a given stand.

Silvicultural practices for minimizing shoot borer damage include establishment of hosts on sites for which they are adapted, since vigorous trees are more tolerant of injury than stressed trees. Maintaining fully stocked stands also reduces the potential for shoot borer damage. Although they are effective in some situations, pesticides are regarded as emergency control measures and are therefore not incorporated into management plans. Future control techniques may include enhancement of biological control agents such as parasites, predators, viruses and bacteria and development of resistant trees via genetic engineering or tree breeding.

Key words: Shoot borers, conifers, _Eucosma_, _Pissodes_, _Rhyacionia_

INTRODUCTION

Insects which attack conifer shoots, particularly those which feed on leaders, cause significant damage to forests in many parts of the world. As forest management becomes more intensive, some shoot-infesting insects which have in the past been regarded as minor pests are becoming more important. Activities by man have exacerbated infestations and/or damage in many cases. Extensive plantings of exotic conifers on marginal sites, accidental introductions of shoot-infesting insects and new cultural practices (control of competing vegetation with herbicides, for example) have sometimes resulted in serious damage to forests.

Damage by shoot borers is often transitory. Many species are pests only during the early stages of stand establishment, attacking seedlings and/or saplings. Once stands approach crown closure, many shoot borers are no longer serious pests, although some, such as the white pine weevil, Pissodes strobi, may continue some attacks through rotation (Harman 1971).

Available space does not permit us to thoroughly review the literature on shoot boring insects here. We therefore have selected some representative species within four genera which are regarded as serious pests in at least part of their ranges. Representatives of the genera discussed here occur in many parts of the world where pines and other conifers are grown for commercial purposes. We have elected to discuss representatives of the genera Eucosma (Lepidoptera: Tortricidae), Pissodes (Coleoptera: Curculionidae) and Rhyacionia (Lepidoptera: Tortricidae).

REVIEW OF SOME IMPORTANT SPECIES

Eucosma

Two species of Eucosma attack conifer shoot tips in North America. The eastern pine shoot borer, E. gloriola Heinrich, occurs in the northeastern U.S.A. and southeastern Canada throughout much of the range of its principal host, eastern white pine (Pinus strobus). Other hosts include jack pine (P. banksiana), Scotch pine (P. sylvestris), red pine (P. resinosa), and several other non-native conifers (DeBoo et al. 1971). The western pine shoot borer, E. sonomana Kearfott, occurs throughout the western U.S.A. and in southwest Canada. All western yellow pines may be attacked, but the most common hosts include ponderosa pine (P. ponderosa), lodgepole pine (P. contorta), and Jeffery pine (P. jeffreyi) (Grant 1958, Sartwell et al. 1980). Adults of both Eucosma species are similar in appearance, but can be distinguished by alar expanse and size of male genitalia both of which are larger on E. sonomana (DeBoo et al. 1971).

Both species are univoltine and they have similar life histories (DeBoo et al. 1971, Mitchell and Sower 1988). Adults begin to emerge in the spring prior to initiation of host tree shoot growth. Eggs are apparently laid singly or in groups of five or less on the buds and needle sheaths near the shoot tips. Neonate larvae bore into the expanding shoots and feed in the pith region. The mature fifth instar larvae bore exit holes and drop to the ground to pupate in the litter. Larval development is complete by mid-August in most areas. The larvae are solitary feeders and there is usually only one insect per shoot. Leaders are infested more often than lateral shoots, particularly in small trees and at low population densities.

Feeding by Eucosma spp. larvae can cause loss of tree growth and form. Infested shoots are stunted with shortened needles and they may die if the vascular tissue is severed or if the stem breaks because of structural weakening. Infested leaders may lose dominance to healthy lateral shoots resulting in a crook, fork, or bushy top (Grant 1958, DeBoo et al. 1971, Stevens and Jennings 1977). Ponderosa pine shoots lose the equivalent of 25% of one years height growth for each year that they are successfully attacked by *E. sonomana* (Stoszek 1973, Sower et al. 1989). Assessing the impact of *E. sonomana* infestation on pine growth is difficult because the most vigorous trees in a stand have the highest probability of being attacked (Sower and Mitchell 1987, Ross 1989). Consequently, infested shoots on vigorous trees may grow as much as uninfested shoots on adjacent less vigorous trees. Both species may attack trees ranging from 1 m to over 10 m in height, but *E. gloriola* infestations have been reported to decrease substantially following crown closure in dense stands (DeBoo et al. 1971).

Certain silvicultural treatments designed to improve pine survival and growth, such as site preparation, may increase the rate of development of *E. sonomana* infestations (Ross 1989). Open grown stands of ponderosa pine were most susceptible to *E. sonomana* in British Columbia (Grant 1958), but shoot borer response to thinning has not been reported. Control of *Eucosma* spp. will become increasingly important in intensively managed conifer plantations representing large economic investments. Attempts to control *Eucosma* spp. with insecticides have been unsuccessful (DeBoo 1971, Stevens and Jennings 1977). Cultural controls including clipping infested shoot tips, planting resistant species, and controlled burning to destroy the overwintering habitat have been suggested, but not tested (Deboo 1971, Stevens and Jennings 1977). Some natural enemies of *E. gloriola* have been described, but their effects on shoot borer population dynamics are unknown (DeBoo 1971). Effective methods of controlling *E. sonomana* by disrupting mating with synthetic sex attractants have been developed and tested at the operational level (Sower et al. 1989). The effects of *E. sonomana* mating-disruption treatments last for two or three generations (Sower et al. 1989). A single mating-disruption treatment applied early in plantation establishment provided the greatest economic benefits in northern California (Williams et al. 1989).

Pissodes

Three species of *Pissodes* attack the terminals and one-year-old stems of conifers in North America (Smith and Sugden 1969). The most economically important species is *P. strobi* (Peck) (=*engelmanii* Hopkins, =*sitchensis* Hopkins), the white pine weevil (=Engelmann spruce weevil, =Sitka spruce weevil). This species occurs throughout much of North America and attacks many conifer species in the genera *Pinus* and *Picea*. Three distinct populations are associated with the principal hosts, eastern white pine, Engelmann spruce (*Picea engelmannii*), and Sitka spruce (*P. sitchensis*) (Wallace and Sullivan 1985). The yellow-spotted pine weevil, *P. nitidus* Roelofs, attacks one-year-old leaders of pines in northeast China, the far east of the Soviet Union, Japan, and Korea (Liyuan 1989). Its hosts include Korean pine (*P. koraiensis*), Chinese red pine (*P. tabulaeformis*), and several other *Pinus* species.

Both *P. strobi* and *P. nitidus* are univoltine and they have similar life histories (Wallace and Sullivan 1985, Liyuan 1989). Adults overwinter primarily in the litter near the base of host trees, although in mild climates they may overwinter on the trees. The adults become active during April when they move to the tops of tree crowns to feed, mate, and oviposit. In the spring, male *P. strobi* produce an aggregation pheromone that is attractive to both sexes of weevils (Booth and Lanier 1974). Adults feed on the inner bark of one-year-old leaders, and females deposit one to several eggs in the base of some of the feeding punctures. As many as 200 eggs may be deposited on a single leader. The larvae feed downward on the inner bark and usually girdle the stem. The mature larvae remove shreds of wood [illegible] form chip cocoons in which they pupate. Adults begin emerging in August and feed in the upper crown until they are induced to hibernate by cool temperatures and decreasing daylength. Adults may live up to four years.

Feeding by *Pissodes* spp. larvae often kills at least two years of leader growth. A single attack can result in the loss of over 30 cm of height growth in some conifer species (Houseweart and Knight 1986, Liyuan 1989). In addition, damaged leaders are usually replaced by one or more lateral shoots resulting in a scar, crook, or fork in the main stem that can affect lumber recovery (Alfaro 1989, Liyuan 1989). Trees that suffer repeated attacks can become so deformed that they are unmerchantable as sawlogs. Vigorous, open-grown trees are most susceptible to *Pissodes* attack, due, at least in part, to the effects of microclimate on weevil behavior and the preference of adults for the largest available leaders (Wallace and Sullivan 1985). Both physical and chemical tree attributes are involved in host finding and acceptance by *P. strobi* (Alfaro and Borden 1985). In some areas the potential for damage by *Pissodes* spp. may be the primary factor influencing silvicultural decisions, including selection of planting stock.

Despite considerable research on the biology and ecology of *Pissodes* spp., options for control are limited. Individual host tree differences in susceptibility to weevil attack have been observed, but the potential for breeding resistant varieties has not been fully evaluated (Garrett 1986). Chemical control of *Pissodes* is possible, but insecticide applications must (1) be timed to coincide with adult activity and (2) result in thorough coverage of host tree leaders (de Groot 1985). Clipping and destroying infested leaders has been a recommended control for many years, and can be effective for isolated infestations. Parasites and predators can be separated from weevils in clipped shoots and released back into a stand to minimize adverse impacts on natural control (Hulme et al. 1986, Liyuan 1989). Silvicultural systems that exploit the natural protection provided by shaded environments without drastically reducing crop tree growth are currently being developed to minimize damage by *P. stobi* (Stiell and Berry 1985).

Rhyacionia

Rhyacionia frustrana

The Nantucket pine tip moth, *R. frustrana* (Comstock), is perhaps the most common, intensively studied, and economically important native *Rhyacionia* species in North America (Berisford 1988). The natural range of *R. frustrana* occupies most of eastern U.S.A. and extends southward through Central America and the Caribbean Islands (Powell and Miller 1978). It has also been introduced into the southwestern part of the U.S.A. *Rhyacionia frustrana* is closely related to *R. bushnelli* (Busck) and the two species are morphologically indistinguishable except that *R. bushnelli* is larger (Miller 1967a). Their habits are similar except that *R. bushnelli* overwinters as pupae on the ground and *R. frustrana* pupae overwinter in infested shoots.

Rhyacionia frustrana attacks most hard pines which occur within its range except *P. palustris*, although host species range from the highly susceptible, *P. taeda* and *P. echinata*, to resistant, *P. elliottii* and *P. caribea*.

Adult *R. frustrana* emerge in late winter or early spring with male emergence preceeding that of females. Mating occurs shortly after emergence and eggs are deposited singly on needles and shoots. Newly hatched larvae initially mine needles but soon move to shoot tips where they construct silk "tents" in bud or needle axils. These structures are the first readily visible evidence of tip moth attack. Later instars bore into buds and/or shoots killing up to fifteen centimeters of shoots depending on shoot diameter and larval density. Tip moths and host phenology are well synchronized in most regions, with a new moth generation coinciding with each new flush of shoot growth. The moth may have from two to six generations annually.

Damage by *R. frustrana* is highly variable, but it is most severe on seedlings and saplings particularly on trees under three years of age. Damage may be confined to some growth loss or it may also include substantial loss of form and lower wood quality. Several studies on impact are cited in Berisford (1988), although documentation of tip moth impact is not complete. Results from different studies are contradictory with some indicating significant damage and others showing no effects on growth or form. Tip moth attack is positively correlated with infection by pathogens such as the pitch canker fungus (Cade et al. 1986). The tip moth normally reaches its highest populations in even-aged stands with wide spacing and little competing vegetation (Berisford and Kulman 1967, Hertel and Benjamin 1977). Low site quality and poor tree nutrition and/or limited availablity of water are conducive to higher damage (Hood et al. 1988, Ross and Berisford 1990).

Management strategies for *R. frustrana* are normally aimed at maintaining the highest possible stand vigor in fully stocked stands. Such stands usually benefit from natural enemies which can cause substantial mortality of the moth (Gargiullo and Berisford 1983). Insecticides are not regularly used in forest stands even though they can be very effective with proper timing. Pesticides are frequently used for high value trees such as Christmas trees, progeny tests, seed orchards or ornamentals. Although a sex pheromone has been identified for *R. frustrana* (Hill et al. 1981), it has not been used for operational control by disruption. However, pheromones have been incorporated into spray timing models (Pickering et al. 1989). Successful control with pheromones has been demonstrated with *R. zozana* in northwestern U.S.A. (Niwa et al. 1988), indicating some possibility for their use on other *Rhyacionia* spp.

With the increasing intensity of forest management, it appears that tip moths will become even more important in the future. Practices such as intensive site preparation and control of herbaceous vegetation increases tree growth, but may also increase populations and impact of *R. frustrana*. Future management may include the use of resistant trees (Berisford 1988), biological insecticides (McLeod et al. 1983), or bioengineered trees (Raffa 1989).

Rhyacionia buoliana

The European pine shoot moth, *R. buoliana* (Schif.) is a pest of young pines in many parts of the world (Speight and Speechly 1982). It is a significant pest in Europe, particularly in Great Britain, Germany, France and Spain. It has been introduced, usually via infested planting stock, into several countries where it has also become a pest in many cases. It is well established in parts of both North and South America. Damage varies considerably depending on host tree species, host condition and climatic conditions.

There are two subspecies of the moth, R. *buoliana* and R. *buoliana thurificana* which have somewhat different life histories and host preferences (Miller 1967b). The R. *buoliana* form is more common and apparently better adapted to colder climates. *Rhyacionia buoliana thurificana* occurs mostly in the Mediterranean region.

The life history of *R. buoliana* is somewhat different from other species of *Rhyacionia* in that they overwinter as small larvae. Eggs are deposited on needles or shoots in early to mid summer. Small larvae feed on the bases of needles and then move to buds. The appearance of pitch blisters or pitch-soaked "tents" is frequently the only evidence of attack at this time. The larvae (usually second instars) cease feeding in late summer and overwinter inside of the buds (Haynes and Butcher 1962). Larvae resume feeding in the spring and frequently move to other buds. The effect of feeding apparently varies with different hosts and host condition. Some of the most serious damage occurs when larvae kill only part of the shoots producing severe crooks and "posthorns" when the undamaged side of the shoots continues to grow. Larvae pupate within the infested shoots and adults emerge and mate in the spring, usually in May or early June in Europe and North America. *Rhyacionia buoliana thurificana* is adapted to warmer climates and can produce two or possibly three overlapping generations per year (Mendel 1987).

In North America, the moth attacks a variety of *Pinus* spp. but the most serious damage occurs on red pine in central and eastern Canada and U.S.A. (Miller 1967a). Favored hosts in western North America are ponderosa pine and lodgepole pine (Carolin and Daterman 1974). Scotch pine is among the most susceptible species in Europe. The moth inflicts serious damage on introduced Monterey pine (*P. radiata*) in South America (Araya and Ramirez 1989). Mendel (1987) reported significant damage to Aleppo pine (*P. halepensis*) in Israel.

Most shoot moth damage occurs on relatively young trees prior to crown closure (Miller 1967b, Pointing and Green 1962, Roberdo 1966). Estimates of losses caused by shoot moth attacks have been made by a number of workers, but techniques for estimation vary considerably making it difficult to compare impacts in different regions. A recent report from Chile estimates that shoot moth attacks reduced stand volume by almost 15 percent when current damage in a nine-year-old Monterey pine stand was extrapolated to rotation age (Araya and Ramirez 1989). However, most studies concentrate on height growth and form losses such as those described by Miller (1967b) and Talerico et al. (1963).

The shoot moth has proven difficult to control by insecticides in forest stands. Although chemicals are sometimes effective, prolonged control requires repeated applications and is therefore not generally economical. Timing of foliar applications of pesticides is critical since larvae are exposed for only a short time (Butcher and Haynes 1960). Systemic insecticides applied to the soil may provide adequate control (Kulman and Dorsey 1962), but application is expensive and adequate soil moisture is required for uptake by the trees.

Other attempts at direct control include the use of a sterile male technique (Chawla et al. 1970) and cultural techniques such as pruning infested shoots to improve form and reduce shoot moth populations (Miller 1967b). The sex pheromone for R. *buoliana* has been successfully used for survey (Daterman 1974), but control with pheromones has not been demonstrated.

Rhyacionia buoliana has a number of natural enemies in its native range which appear to maintain generallly lower populations in Europe than elsewhere

(Harman and Kulman 1973). Several parasites have been successfully transplanted to regions where the moth has been introduced, particularly in North America (Arthur and Juillet 1961). Recent introductions have been made in Chile but evaluations of establishment or impact are not yet available (Aguilar and Beeche 1989). Parasitism appears to be somewhat independent of host population density (Bogenschutz and Lange 1970), but control below economic thresholds has generally not occurred (Arthur and Juillet 1961).

The shoot moth is mainly a pest of trees growing on poor sites or trees not well adapted to certain sites. Heikkenen and Miller (1960) showed that most attacks and damage occurred on slow growing trees. Red pines which had annual height growth of at least 38 cm were not seriously damaged, while those with less growth were attacked and in some cases severely damaged.

The greatest potential for consistent control of the European pine shoot moth is adoption of silvicultural systems which maintain high host vigor. This might be accomplished by minimizing planting on poor sites, favoring those species or varieties which cause high larval mortality (Haynes and Butcher 1962) or perhaps breeding for resistance (Holst and Heimburger 1955). In areas where it has been established for long periods, *R. buoliana* has become somewhat less of a pest, apparently due to *modification of* silvicultural practices and development of natural controls. However, it remains a potential serious threat in regions where it has been recently introduced.

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ESTIMATING THE EFFECTS OF REFORESTATION PESTS ON LONG-TERM WOOD SUPPLY

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SUMMARY

The impact of reforestation pests on forest-level wood supply can be described using techniques whose application shows the importance of obtaining certain types of information about pest damage. This includes long-term pest behaviour, the extent of damage, and the growth and yield of damaged stands.

INTRODUCTION

Research into pests and their impacts has concentrated mainly on short-term tree- and stand-level aspects (see Alfaro 1989a and Thompson and Alfaro 1989 for examples and several references). Little attention has been directed to effects at the forest level, or over a management unit of many stands of various ages which produces a flow of harvest volumes. The solution is not through simple extension of stand-level results since damage from a particular pest does not necessarily occur in all stands in a forest. In this paper pest impacts will be viewed from the standpoint of the forest level, the long term or several decades, and the flow or continuity of harvest.

Insect pests can be placed into two major categories according to the damage which they cause. In the first are pests which cause stand increment losses. These losses can be depicted by a yield curve shift (Figure 1). Pests which kill scattered trees or which slow tree growth are examples. The second category includes pests which cause catastrophic losses, or sudden extensive mortality. These are pests which can affect the lifetime of a stand (Figure 2) and alter the age or type distribution of stands in a forest. Infestations of this nature can often be time-dependent, occurring in cycles.

Insect pests which attack young stands fall into both these categories, sometimes simultaneously. Their population behaviour can be time-dependent, resulting in catastrophic losses when at epidemic levels and incremental losses when at endemic levels. They can also exhibit age-dependence, with some pests causing seedling mortality in young plantations or reduced growth of saplings in older stands. For these reasons, modelling the impact of such pests at the forest level can be difficult.

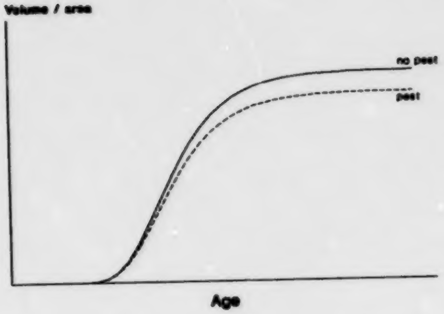

Figure 1 Schematic illustration of stand increment losses.

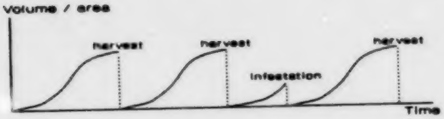

Figure 2 Schematic illustration of catastrophic losses.

FOREST EVOLUTION WITH PESTS PRESENT

The evolution of an imaginary forest will now be presented to illustrate how the impacts of reforestation pests on forest-level output might be determined.

Consider, first, the case of no pest. Figure 3 represents a forest consisting, initially, of 100 hectares in each of five age classes. Areas which are harvested move to the first age class (if there is immediate regeneration) and the remaining areas advance by one age class to represent ageing. This process continues from decade to decade. These dynamics are common to existing forest-level models such as Timber RAM (Navon 1971), FORPLAN (Johnson, Jones, and Kent 1980), and TREES (Tedder 1980).

FOREST LEVEL DYNAMICS

No Pest

Area By Age Class

	1	2	3	4	5
Decade 1 Inventory	**100**	**100**	**100**	**100**	**100**
Decade 1 Harvest				**50**	**100**
Decade 2 Inventory	**150**	**100**	**100**	**100**	**50**

and so on . . .

Figure 3 Dynamics of an imaginary forest where no pest is present.

In the case where reforestation pests are present it is useful to divide the forest into uninfested and infested categories (Figure 4).

FOREST LEVEL DYNAMICS

Pest included *(2% area infested / decade)*

Area By Age Class

	Uninfested					Infested				
	1	2	3	4	5	1	2	3	4	5
Decade 1 Inventory	**100**	**100**	**100**	**100**	**100**					
Decade 1 Harvest				**50**	**100**					
Decade 2 Inventory	**150**	**98**	**98**	**98**	**49**	**0**	**2**	**2**	**2**	**1**

and so on . . .

Figure 4 Dynamics of an imaginary forest subject to pest infestation, where pest losses occur at all ages.

In this example, the areas not harvested are subject to pest infestation. Thus 2 percent of these areas are transferred to the infested-timber category and aged one age class. The remaining areas are advanced one age class, as before. These dynamics take place from decade to decade. Note that it is not a requirement that infestations be at the same level of activity each decade. Nor is it necessary to impose pest infestations on all ages or have regeneration take place immediately. The arithmetic of the above examples is simply adjusted to account for particular circumstances.

Stand yield information is used to determine the total volume or value of timber harvested or salvaged. This is obtained by multiplying the volume or value per area by the area harvested. The infested timber category will have a different yield relation. For the volume case, one possibility has been presented schematically in Figure 1 for stand increment losses. Another possibility is given in Figure 5, where the solid line represents the yield which would be applied to a stand after it has been transferred to the infested category. In this case, this infested-stand yield relation shows the possible development of surviving trees in a stand which has been subjected to a catastrophic-like loss.

It is through these different relations that the effects of pest infestation on forest-level output, such as harvest flow, can be evaluated.

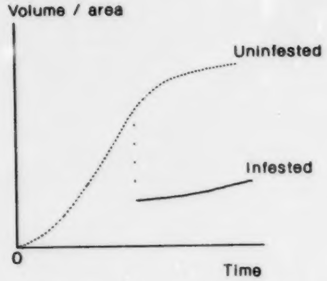

Figure 5 Schematic representation of possible yield relation for an uninfested and infested stand of the same type. The solid line represents the yield used for a stand in the infested category.

The forest-level techniques described above are particularly suited to the investigation of impacts of pests which attack young forests. Such pests have little impact on the current value of the growing stock since the stands which they infest have little or no current value. The effect which these pests have is on the future flow of harvests. Forest-level analysis can show how stands of various ages contribute to the harvest schedule and therefore illustrate the impact of their volumes being unavailable for future harvest if they are damaged or destroyed.

For a more complete discussion of modelling the effects of pests at the forest level the reader is referred to Reed and Errico (1987).

EXAMPLE

An example from the Bulkley Timber Supply Area (TSA) of British Columbia is now given. This example is drawn from a larger study which investigated several pests and their impacts[1]. In this example, only existing stands of predominantly lodgepole pine (*Pinus contorta* Dougl.) are included and treated as though they form their own management unit producing a flow of timber.

Table 1 gives the age-class distribution for this type. There are approximately 50 000 hectares in total.

Table 1 Age-class distribution for stands of predominantly lodgepole pine (*Pinus contorta* Dougl.) on sites of site index 19-24 m (base age 100) in the Bulkley TSA

Age-Range (years)	Area (ha)
0 - 20	5895
21 - 40	627
41 - 60	4529
61 - 80	5987
81 - 100	6071
101 - 120	9200
121 - 140	5041
141 - 250	10825

One of the regeneration options for denuded lodgepole pine sites is to plant with interior white spruce (*Picea glauca* (Moench) Voss) seedlings. Figure 6 illustrates the volume-age relations for both these types.

In order to make timber-supply projections using the methods presented earlier, three additional rules are now introduced:

1. Existing lodgepole pine sites will be regenerated immediately, with 60 percent of sites being regenerated with lodgepole pine and 40 percent of sites being regenerated with spruce.

2. The desired harvest level for the first 5 years is 250 000 cubic metres per year. After that, a harvest level equal to 14% of total growing stock volume is desired. These rules were chosen to provide projections of representative harvest levels for this area.

3. Oldest stands are harvested first, with a minimum harvest age of 75 years used for lodgepole pine stands and 100 years used for spruce stands.

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[1] Errico, D. and Geisler, M. B. 1989. The effects of some major pests on the wood supply of the Bulkley Timber Supply Area. British Columbia Forest Service, Research Branch, unpublished report.

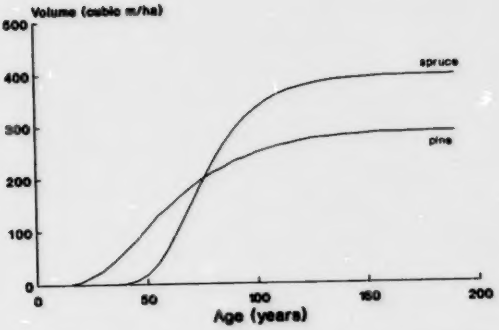

Figure 6 Volume-age relations for lodgepole pine (*Pinus contorta* Dougl.) and white spruce (*Picea glauca* (Moench) Voss) on medium sites.

Combining these rules gives the harvest schedule in Figure 7.

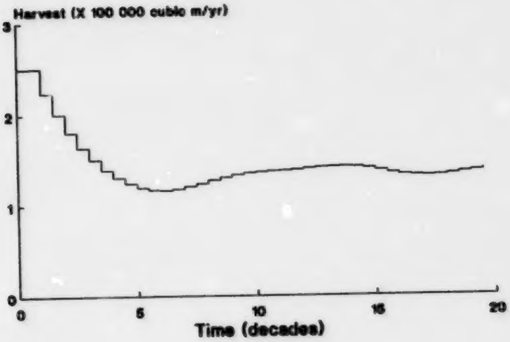

Figure 7 Harvest schedule for medium site lodgepole pine in the Bulkley TSA for the reference case of no pest.

This represents the reference case, where there is no pest. The harvest schedule indicates a liquidation of the existing mature lodgepole pine stands; settling down to a long-run sustained yield. Note that this harvest flow, for later years, is made up of volumes from spruce and pine stands.

Young spruce stands are susceptible to attack by spruce weevil (*Pissodes strobi* Peck.) (also known as white pine weevil) which destroys the leader of white spruce of approximate age range of 10 to 30 years. Damage from this pest includes reduced height growth as well as loss in wood quality (Alfaro 1989b).

For this region, little is known about long-term weevil behaviour, the extent of area damaged during an infestation, and the reductions in volume or value per area for damaged stands. Three studies, however, have been recently conducted in other areas of British Columbia to determine the current extent of spruce weevil damage. These areas include the British Columbia Forest Service Vancouver and Cariboo Forest Regions and the Prince George TSA. Estimates are reported in Table 2.

Alfaro (1988) reported on a method to project the growth and yield of a Sitka spruce (*Picea sitchensis* (Bong.) Carr.) stand on the coast of British Columbia under the influence of weevil. From this work approximate yield reductions for different attack intensities were estimated and used for the white spruce of the present example[2]. This information is also presented in Table 2.

Table 2 Summary of spruce weevil infestation intensities, extents, and volume/ha reductions.

		% Area Infested			
Attack Intensity	% Stems Attacked	Vancouver Region	Cariboo Region	Prince George TSA	% Yield Reduction
None	<.01	20	15	70	0
Light	.01 - 10	60	50	25	11
Medium	10.01 - 25	10	5	5	34
Heavy	25+	10	30	0	53

It should be remembered that the area estimates for the three categories of infestation intensity represent a set of observations for a single time and do not indicate how these levels will change. For the purposes of illustration, these levels are assumed to be at equilibrium and persist indefinitely. See Alfaro (1982) and Alfaro and Omule (1990) for a more complete description of the epidemiology of the spruce weevil.

Figure 8 shows harvest projections using the estimates of Table 2. Projections are sensitive to the estimate of extent of weevil infestation, with impacts ranging from minor (for the Prince George TSA estimates) to approaching significance (for the Cariboo Region estimates). Thus, reliable estimates of weevil infestation are important. Note that for any of the projections incorporating weevil damage the reduction in harvest level occurs sometime in the future when damaged stands are finally harvested.

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[2] I am grateful for the assistance of Dr. Alfaro, Forestry Canada, in defining categories of spruce weevil attack levels and estimating volume reductions.

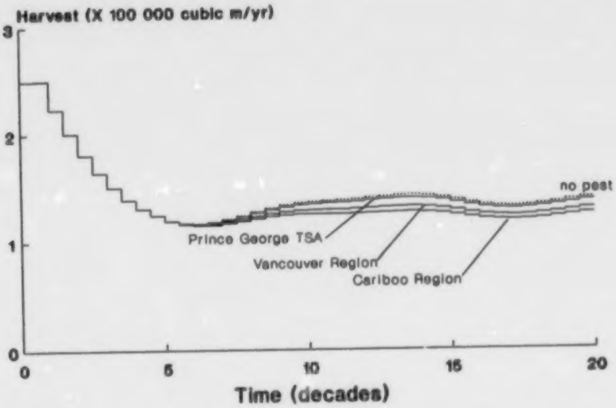

Figure 8 Harvest schedules incorporating the effects of spruce weevil using the estimates of Table 4 and assuming that these levels would persist. Provided for comparison is the schedule for the no-pest reference case.

An additional scenario concerning spruce weevil is considered. Stand managers suggest[3] that a viable management option is to rehabilitate heavily attacked sites after infestation, rather than allow them to continue to grow to yield a reduced volume. The wood-supply implications of this can be tested using the above techniques. Figure 9 shows the harvest schedule where all heavily infested spruce sites are rehabilitated and restocked with spruce seedlings after 15 years of age, possibly to be re-infested with weevil. The attack levels for the Cariboo Region were employed. The previously displayed projection where these damaged stands are not rehabilitated, but allowed to continue to grow, is also illustrated.

Figure 9 shows higher harvest levels for the rehabilitation option. Thus where volume damage is high, it might be preferable to rehabilitate and restock an infested site, (so long as re-establishment costs are not prohibitive) rather than allow the existing damaged site to continue to grow. The lost growing time brought about by the weevil infestation and subsequent rehabilitation is preferable to the lower yield of the damaged stand. Note that if stands of commercial yield comparable to spruce were to naturally succeed in the same 15-year time frame due to suppression of weevil-damaged trees, similar higher harvest levels will result.

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[3] M. B. Geisler, British Columbia Forest Service, personal communication

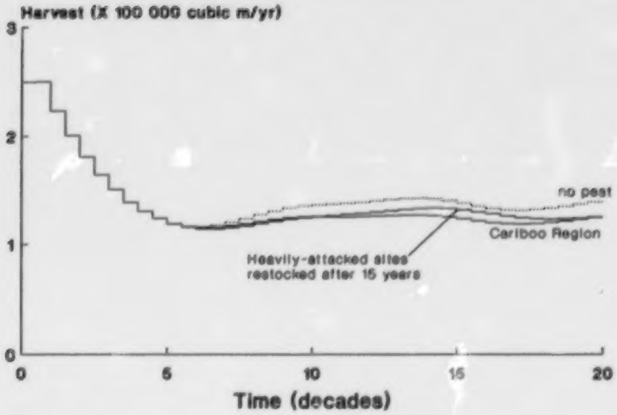

Figure 9 Harvest schedules using the Cariboo Region estimates and where heavily infested sites may or may not be restocked with spruce after 15 years. Shown for comparison is the no-pest case.

DISCUSSION

The examples given above are very simple. They do not include value effects and changes in wood production costs per cubic metre.

The examples do, nevertheless, show how such techniques can be used to display the effects of pests which attack young stands, by showing their ultimate effect on future harvest levels. They also show the importance of obtaining good information regarding pests. Specifically, this includes:

1. Pest population behaviour over the long term (timing and nature of cycles over several decades).

2. Extent of area infested (the proportion of a type that is infested).

3. Changes in volume or value yield per unit area on infested sites. This item is concerned with the growth and yield of an infested stand.

If it is desired to investigate the impact of pest infestation upon wood supply, this data is required. Without this information such analyses cannot be conducted.

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LOS PULGONES DE LAS CONIFERAS EN ESPAÑA

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RESUMEN

Este trabajo trata del estudio de los pulgones presentes en determinadas coníferas de España. Debido a los graves problemas que ocasionan en los árboles, su análisis y seguimiento adquieren un máximo interés en el contexto de la protección forestal.

Palabras clave: Afidos, protección forestal.

SUMMARY

The paper deals with the study of aphids living on some spanish conifers. The analysis and monitoring of these aphid populations is particularly relevant in forest protection grounds, so long as the problems they cause in trees are most important.

Keywords: Aphids, forest protection.

INTRODUCCION

Hasta hace poco tiempo, la incidencia que han tenido los ataques de los pulgones en diversas coníferas españolas no podía considerarse como de extraordinaria trascendencia. Sin embargo, en las dos últimas décadas se presentaron daños muy importantes causados por estos insectos en especial los pertenecientes a las familias Lachnidae, Adelgidae y Mindaridae.

Los perjuicios que ocasionan pueden ser directos o indirectos. Los primeros (marchitamiento, deformación y atrofiamiento de brotes, defoliación, abortamiento de flores, caída de frutos y formación de agallas y pseudoagallas) son provocados por la absorción de savia, y los segundos (aparición de "negrilla" y transmisión de virus) son causados por otros agentes distintos a los cuales les facilitan su instalación en la planta.

Sin perjuicio de que todos ellos tienen una importancia bastante considerable, la implantación de la "negrilla" llega a ser, en algunos casos, fundamental. Es sabido que la mayor parte de los pulgones posee unas estructuras conocidas con el nombre de cornículos, tubos localizados sobre el dorso del sexto segmento adbominal. En principio era creencia general que tales tubos servían para excretar una sustancia azucarada, el rocío-miel o mielato; pero investigaciones llevadas a cabo en los años setenta demostraron que estaban conectados con glándulas productoras de secreciones céreas, básicamente triglicéridos de hexanoico, hexanodienoico y otros ácidos, y utilizadas por el insecto como feromonas de alarma.

El verdadero mielato, compuesto por la savia ingerida y por azúcares excedentes y material de excreción, lo emite el pulgón a través del ano. Todas estas sustancias constituyen un medio óptimo para el desarrollo de determinadas especies de hongos. Tales hongos forman en la planta hospedante una capa compacta que impide la penetración de la luz hasta las células asimiladoras, constituyendo entonces un obstáculo para la función clorofílica, para los cambios gaseosos de la asimilación del carbono y de la respiración e incluso para la transpiración. Estos saprofitos no provocan directamente la muerte de la planta, aunque bien es verdad que la debilitan debido a que impiden la normal realización de sus funciones vitales más importantes. Si, por otra parte, el ataque de los pulgones es intenso y continuado, la planta sucumbe más tarde o más temprano.

Por todo esto, es esencial el conocer las especies de estos insectos que puedan presentar un peligro real o potencial a las repoblaciones y bosques ya implantados. Y también el investigar sus respectivos ciclos biológicos porque de ellos pueden emanar resultados útiles para alcanzar un control efectivo.

Autores como Gómez Menor (1962), Nieto Nafría (1972), Nieto Nafría y Mier Durante (1984), Meliá (1978), Notario et al. (1978, 1984), Binazzi et al. (1983) informaron, con mayor o menor amplitud, sobre ciertas especies que se comportaron como enemigos de determinadas coníferas establecidas en suelo español. La relación de dichas especies, sin que por supuesto pueda considearse como exhaustiva, es la siguiente: Cinara acutirostris (sobre Pinus pinaster, P. halepensis y P. nigra), Cinara balachowsky (sobre Pinus halepensis), Cinara cedri (sobre Cedrus atlantica y C. deodara), Cinara cupressi (sobre Cupressus sp.), Cinara excelsae (sobre Pinus pinaster, P. sylvestris y Pinus sp.), Cinara guadarramae (sobre Pinus sylvestris), Cinara juniperi (sobre Juniperus communis), Cinara maghrebica (sobre Pinus pinaster, P. halepensis y P. nigra), Cinara maritimae (sobre Pinus pinaster, P. halepensis y P. nigra) Cinara palaestinensis (sobre Pinus halepensis), Cinara piceae (sobre Abies sp. y Picea excelsa), Cinara pini (sobre Pinus pinaster, P. halepensis y P. nigra), Cinara pinicola (sobre Picea sp.), Cinara pinihabitans (sobre Pinus sylvestris), Cinara tujafilina (sobre Thuja delobrata), Cedrobium laportei (sobre Cedrus atlantica), Eulachnus agilis (sobre Pinus sylvestris, P. pinaster y P. halepensis), Eulachnus nigricola (sobre Pinus pinaster, P. halepensis y P. nigra), Eulachnus rileyi (sobre Pinus pinaster, P. halepensis y P. nigra), Eulachnus tuberculostemmatus (sobre Pinus pinaster, P. halepensis y P. nigra), y Shizolachnus pineti (sobre Pinus pinaster, P. sylvestris, P. halepensis y P. nigra).

Notario y Baragaño, en el periodo comprendido entre 1986 y 1989, abordan un proyecto subvencionado por el Instituto Nacional para la Conservación de la Naturaleza con el objetivo fundamental de ampliar los conocimientos sobre la afidofauna presente en los montes de coníferas.

MATERIAL Y METODOS

Las prospecciones de insectos se llevaron a cabo en 14 provincias españolas: Madrid (Dehesa de la Villa, Casa de Campo, Tres Cantos, Alpedrete); Granada (Sierra de Baza); Huelva (Monte Los Cabezudos); Jaen (Lugar Nuevo); Navarra (Elizondo); Teruel (Rubielos de Mora); Huesca (Jaca); Murcia (Puerto de Mazarrón); Alicante; Cuenca (Priego); Santa Cruz de Tenerife; Salamanca; Soria; Segovia (Montuenga, Coca).

Los pulgones recogidos de los árboles fueron conservados en un líquido compuesto por alcohol de 70° y ácido láctico en la proporción de 1:3. Este líquido impide la excesiva y rápida deshidratación del tegumento, con lo que el tejido presenta una aceptable clarificación al mismo tiempo que no se produce ni hinchamiento ni deformación de los apéndices.

En cuanto a la preparación de los especímenes en el laboratorio se siguió el siguiente método:

- Inmersión en cloralfenol.

- Lavado en agua templada y aplastamiento suave con el pincel para la total expulsión del cloralfenol.

- Colocación de una gota de Berlesse (goma arábiga cubierta por una tela fina que se disuelve en agua durante aproximadamente 10 días) en el porta-objetos junto con el especimen.

- Preparación del especimen utilizando el microscopio estereoscópico.

- Secado de la preparación a la temperatura ambiente durante 45 a 60 minutos.

- Adición de una o varias gotas de Berlesse sobre el especimen.

- Secado en estufa a 40°C durante 8 o 15 días.

Para la identificación taxonómica, que se basa principalmente en mediciones micrométricas (Binazzi, 1978, 1984), fue utilizado el dispositivo digital de medición MMS 235 con impresora incorporada adaptado a un microscopio estereoscópico WILD M 5. Este dispositivo, con un campo y precisión de medición de 250 mm. y 2,5 micras respectivamente, permite, después de un proceso de contraste para cada aumento, leer constantemente en un indicador digital las medidas de longitud en el objeto. La placa de medición de contraste está provista de marcas de medición para 6 márgenes de aumento. El operador elige las distancias de contraste visibles en el campo visual y regula la correspondiente memoria en el aparato de mando. Después, el operador desplaza el trazo origen y la marca de medición con ayuda del ocular y los lee pulsando una tecla. Estos datos son procesados mediante el programa de mando y almacenados como valor de contraste para el aumento regulado. El operador puede iniciar de inmediato las mediciones, en cuyo caso las señales emitidas por el ocular de medición son procesadas permanentemente mediante el microprocesador. Los datos son llevados por un lado a la pantalla y por otro a la impresora a la salida de la cual las mediciones son numeradas de una forma continua.

RESULTADOS

ADELGIDAE

I.- ADELGINI

Cholodkovskya viridana sobre *Larix kaempferi*; *Adelges laricis* sobre *L. kaempferi*.

II.- SACCHIPHANTINI

Sacchiphantes abietis sobre *Picea* sp.

MINDARIDAE

Mindarus abietinus sobre *Abies* sp.

LACHNIDAE

I.- CINARINI

Cinara acutirostris sobre *Pinus pinaster*, *P. halepensis* y *P. nigra*; *Cinara cupressi* sobre *Thuja occidentalis* y *Cupressus arizonica*; *Cinara laricis* sobre *Larix kaempferi*; *Cinara maritimae* sobre *Pinus canariensis*, *P. pinaster* y *P. halepensis*; *Cinara maghrebica* sobre *Pinus halepensis*, *P. pinaster* y *P. nigra*; *Cinara pilicornis* sobre *Abies* sp.; *Cinara pini* sobre *Pinus pinaster*, *P. halepensis* y *P. nigra*; *Cinara pinea* sobre *Pinus* sp.; *Cinara pruinosa* sobre *Picea* sp.; *Cinara schimitschekyi* sobre *Pinus nigra*.

II.- SCHIZOLACHNINI

Schizolachnus pineti sobre *Pinus pinaster* y *P. nigra*.

III.- EULACHNINI

Eulachnus mediterraneus sobre *Pinus pinaster*, *P. halepensis* y *P. nigra*; *Eulachnus nigricola* sobre *Pinus pinaster*, *P. halepensis* y *P. nigra*; *Eulachnus rileyi* sobre *Pinus halepensis*; *Eulachnus rileyi* subsp. *tauricus* sobre *Pinus pinaster*, *P. halepensis* y *P. nigra*; *Eulachnus tuberculostemmatus* sobre *Pinus pinaster*, *P. halepensis* y *P. nigra*.

DISCUSION

1.- De estas 20 especies citadas, una es nueva para la entomofauna mundial, *Eulachnus mediterraneus* (Binazzi, 1983), y ocho que se citan por primera vez en España: *Cholodkovskya viridana*, *Sacchiphantes abietis* y *Cinara schimitscheki* (Notario *et al*., 1987), *Adelges laricis*, *Mindarus abietinus*, *Cinara laricis*, *Cinara pruinosa* y *Eulachnus rileyi* subs. *tauricus*.

2.- De todas las localidades geográficas españolas anteriormente referenciadas, la que más interés presenta es la Sierra de Baza ubicada en la provincia de Granada. Durante 1980 se detectó una fuerte infestación de pulgones en el Monte los Frailes, de 627 Has., que había sido repoblado entre los años 1961 y 1964 con *Pinus pinaster* y *P. nigra*. En marzo de 1981 la plaga se extendió a los montes Rivero y la Semana, colindantes con el anterior aunque situados en cotas más bajas y donde las repoblaciones eran más jóvenes, incluyendo además de las dos especies de pinos citados, a *Pinus halepensis*. Después de colectar abundante material entre los meses de marzo y julio de 1981 y enero de 1982, se llegó a la determinación de nueve áfidos que eran los responsables del ataque (Binazzi *et al*., 1983): *Cinara acutirostris*, *C. maghrebica*, *C. maritimae*, *C. pini*, *Eulachnus nigricola*, *E. rileyi*, *E. rileyi* subsp. *tauricus*, *E. tuberculostemmatus* y *Schizolachnus pineti*. Más tarde se descubrió la especie nueva *Eulachnus mediterraneus*.

Se consideró que la causa principal del rápido aumento y extraordinaria expansión de las poblaciones de áfidos podía tener relación directa con la sequía prolongada a la que la zona estuvo sometida durante los años anteriores. Como consecuencia de ello, las nuevas condiciones ambientales de temperatura y humedad relativa y, posiblemente, el progresivo debilitamiento de la repoblación permitieron que las pequeñas poblaciones de pulgones, inadvertidas hasta entonces y, por supuesto, si no inocuas, sí perfectamente tolerables, traspasaran el umbral de daños admisibles, convirtiéndose en una auténtica plaga. Esta plaga pudo ser controlada mediante un tratamiento junto con la explosión imprevista demográfica del excelente predador *Coccinella septempunctata*.

En el invierno de 1987-88 se repite el fenómeno. Como antes, el foco inicial aparece en el Monte los Frailes extendiéndose a los terrenos anejos en dirección NW (Monte las Moras, Monte Ribero y Monte Bastidos) y SE (Monte Retamar y Monte el Cervón) en un total de aproximadamente 2.000 Has. Las especies de pulgones que atacaban, de mayor a menor abundancia, eran: *Cinara maritimae*, *C. acutirostris*, *C. maghrebica*, *Eulachnus rileyi* y *Schizolachnus pineti*. El tratamiento, a base de malathion al 4% a razón de 20 Kg./Ha., se realizó con avioneta por bandas mediante espolvoreo en la primera semana del mes de marzo con resultados aceptables.

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ROOT AND ROOT COLLAR INSECTS IN FORESTRY: NORTH AMERICA

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SUMMARY

Root and collar insects in North America include several long-lived species, characterized by patchy distribution, often high densities, and in several cases cyclic populations. Certain weevils and white grubs continue to be damaging in nurseries and plantations. At the same time, new evidence increasingly implicates various root insects as contributors to complex conifer diseases, such as "red pine pocket decline", "black stain root disease", and "spruce-fir decline". Under nursery conditions, prevention and control largely employ organophosphate and carbamate insecticides, while in the field, cultural controls relying on site amelioration, tree species considerations or timing aspects are providing choices. The use of nematodes for biological control is a promising innovation.

Keywords: Root insects, *Hylobius*, *Phyllophaga*, declines

INTRODUCTION

Various nematodes, insects and rodents are known to impact trees in North America through below-ground herbivory (Andersen 1987). Their often small size, and the complexities inherent in labor-intensive and long-term field research in a "difficult" environment such as soil, probably account for the limited knowledge about these forest pests. In the review presented here, selected literature will be evaluated in an attempt to provide a summary and update on those stages of insects known to damage the roots and root collar region of living trees in North America, highlighting the better known and more important species.

TAXONOMIC OVERVIEW

Most of the insects concerned belong to five orders (Table 1). Among these, certain weevils (*Hylobius* and *Otiorhynchus* spp.) and white grubs (*Phyllophaga* spp.) are presently best known, and considered most significant in ecological and economic terms.

Table 1: Survey of North American taxa of insects with stages damaging to the roots and root collar regions of live trees (* - exotic).

COLEOPTERA	
Buprestidae	*Agrilus horni*
Cerambycidae	*Derobrachus*; *Prionus*
Curculionidae	*Calomycterus*; *Cyrtepistomus castaneus**; *Hylobius aliradicis*, *H. pinicola*, *H. radicis*, *H. rhizophagus* (- *assimilis*) and *H. warreni*; *Nemocestes*; *Otiorhynchus* (- *Brachyrhinus*) *ovatus**, *O. rugosostriatus**, and *O. sulcatus**; *Pachnaeus*; *Pantomorus*; *Phyllobius intrusus**; *Pseudocneorhinus*; *Sciopithes*; *Steremnius carinatus*; *Pissodes fasciatus*
Elateridae	
Scarabaeidae	*Aphodius*; *Dichelonyx*; *Diplotaxis*; *Phyllophaga*; *Pleocoma*; *Polyphylla*; *Serica*
Scolytidae	*Dendroctonus terebrans*, and *D. valens*; *Hylastes nigrinus* and *H. porculus*; *Hylurgops*
DIPTERA	
Anthomyiidae	*Hylemya*
HOMOPTERA	
Aphididae	*Eriosoma*; *Prociphilus*; *Rhizomaria (-Pemphigus) piceae*
Cicadidae	*Magicicada*; *Okanagana*
LEPIDOPTERA	
Hepialidae	*Hepialus gracilis*; *Sthenopis*
Noctuidae	
Sesiidae	*Aegeria tibialis pacifica*; *Sannina*; *Sesia*; *Synanthedon*
ORTHOPTERA	
Gryllotalpidae	*Gryllotalpa gryllotalpa*; *Scapteriscus*

BIOLOGY

The life history of most root and root collar insects in their below-ground phases is poorly understood. Considering the fairly large number of different families involved, it is difficult to generalize, but a few characteristics, applicable to several of them deserve to be pointed out.

The majority of root and root collar feeders spend the bulk of their existence as immatures below ground. Several of them have among the highest life expectancies known in insects, such as the 13- and 17-year cicadas. Three to five year life cycles are common among white grubs, and *Hylobius* weevils may live up to two years as larvae and at least three as beetles. Most of the other rootfeeders seem to have life cycles in the one to two year range, while aphids, root maggots and southern scolytids may produce several generations per year.

The population dynamics of cicadas is remarkable, in that distinctive "broods" exhibit cyclic and spectacular mass emergences (Dybas and Davis 1962), which are highly predictable. In the case of certain scarabs, cyclic patterns and broods have also been documented (Shenefelt and Simkover 1951), but for several reasons these tend to be less distinct and reliable (Sutton and Stone Jr. 1974).

Besides temporal peaks in the abundance of some root insects, their spatial distribution also tends to be patchy. However, very high densities are possible. For 17-year cicadas, mean densities of up to 260 nymphs/m^2, corresponding to a live nymph biomass of 3685 kg/ha were estimated, the "highest mean biomass per unit of habitat recorded for a terrestrial animal under natural conditions" (Dybas and Davis 1962). Patchy distribution and densities as high as 130 grubs/m^2 (~1300 kg/ha live weight) have also been observed for scarabs (Sutton and Stone 1974), and similarly high larval densities (100/m^2) were reported for the conifer swift moth, *H. gracilis*, the equivalent of 160,000 large-sized caterpillars per acre (Wagner et al. 1987; Tobi et al. 1988).

Irregular distribution patterns (horizontal and vertical) for root feeders are ill understood, but most likely reflect food preferences, other environmental influences (Raffa and Hunt 1989), or aspects of inherent mobility. As adults, a remarkably large number of root and root collar feeders either rarely fly (*H. radicis* and some scarab beetles), or are effectively apterous (certain mole crickets and root aphids, *H. warreni* and *Otiorhynchus*). This would seem to curtail long-distance dispersal, while promoting local concentrations. Parthenogenesis, which occurs in some of the aphids and in certain weevils (*Otiorhynchus* spp. and *C. castaneus*), also eliminates the need for extensive mobility.

IMPACTS

Different root insect stages typically affect different hosts or host parts. With exception of mole crickets and some root aphids, immature and adult stages lead quite divergent lives as larvae below and adults partly or entirely above ground. In the case of root feeding Diptera and Lepidoptera, it is only the larvae which damage trees, whereas most scarabs, weevils and the cicadas can damage trees in the immature and adult stage, in which case the larval growth impact is generally more significant.

Rarely are root insects monophagous, like the inconsequential buprestid *A. horni*, which is known to only attack aspen suckers. The woolly elm aphid (*E. americanum*) requires both *Ulmus* and *Amelanchier* for alternating generations. Polyphagous habits seem to be quite common among certain rootfeeders, which may attack a spectrum of woody species in the seedling and sapling categories, but will also include or even prefer non-woody plants, such as ferns and mosses (conifer swift moth), or agricultural crops (cutworms, mole crickets, root maggots, wireworms, white grubs). However, there may be high specificity to host age classes. *Hylobius* and *Otiorhynchus* weevils tend to select conifers up to pole-size, most of the scolytids maturing ones. These classifications must be viewed as tentative, however, because different age classes may vary in tolerance to infestation, thereby complicating attempts to determine actual behavioral preference.

Root and root collar feeders, can affect their hosts in various ways. White grubs, *P. intrusus*, wireworms, cutworms, conifer swift moth caterpillars and mole crickets live in the soil in search of roots, freely consuming smaller, girdling larger ones. On the other hand, cerambycids, *H. rhizophagus*, root maggots, and sesiids spend most of their time as larvae tunnelling through root xylem and/or phloem. Among the root collar insects, the same categories of external (cutworms, *Hylobius* and other weevil adults) and internal feeders (*A. tibialis pacifica*, *H. pinicola*, *H. radicis*, *H. warreni*, *D. terebrans* and *valens*) apply, while *H. aliradicis* engages in both. The homopterous rootfeeders are sapsuckers, cicada nymphs known to specialize on the greatly diluted root xylem sap, a fact that is implicated in their long life cycles (White and Strehl 1978).

Besides these direct effects on trees, insects can also impact tree health and survival indirectly. For instance, the aphid *R. piceae* feed on mycorrhizae of second-growth Douglas fir, and pine root collar weevils have been linked to a greater incidence of *Armillaria* root rot, by providing infection courts for this fungus (Warren and Singh 1970). In recent years various root feeders have increasingly been implicated in complex tree decline phenomena, including "red pine pocket decline" in the Lake States (Raffa and Hall 1988), "blackstain root disease" in the West (Witcosky et al. 1986), and "spruce-fir decline" in the Northeast (Wagner et al. 1987). The role of root-colonizing weevils (*S. carinatus* and *P. fasciatus*), and of the bark beetle *H. nigrinus* as vectors of blackstain root disease (*Verticicladiella wageneri*), is now firmly established. Rootfeeding by *H. gracilis* caterpillars is considered a contributing factor in spruce-fir decline, in conjunction with pollution and other abiotic factors. In the case of red pocket decline, root weevils are thought to predispose trees to subsequent attack by bark beetles.

Direct and indirect damage caused by rootfeeders includes growth loss, mortality and predisposition for secondary stress agents, but detailed physiological or economic analyses are apparently absent. As a result, only survival figures and vague other assessments can be quoted. In many instances, effects will be chronic growth loss (Cerezke 1974) rather than acute damage. This likely reflects a degree of tolerance on the part of plants, which may have enhanced their functional capacities by below-ground organs in response to herbivory (Andersen, 1987).

White grubs (Heit and Henry 1940; Schwardt 1942; Stone and Schwardt 1943; Shenefelt and Simkover 1950 and Sutton and Stone Jr. 1974) and various weevils (MacAloney 1940; Wilson and Schmiege 1965; Cerezke 1974), notably Hylobius and Otiorhynchus, have long been serious pests in nurseries and plantation projects, including Christmas trees and windbreaks. For instance, losses from white grubs have been estimated to amount anywhere from 25% of seedlings (Fowler and Wilson 1974), to "large acreages" (Speers and Schmiege 1971), to almost complete plantation failures (Stone and Schwardt 1943). In some plantations in Canada and the Northeastern USA, more than 90% of Scots pines were killed by H. radicis (Finnegan and Stewart 1962).

Mortality to ornamentals and older field trees, is also possible after prolonged attack by root feeders, especially in conjunction with other complicating factors such as drought (Sutton and Stone Jr. 1974).

Possible ecological impacts resulting from root feeders, are largely speculative. According to Andersen (1987), the indirect effects of below-ground herbivory on the composition and dynamics of plant communities by means of nutrient cycling and soil modification may be great. White grubs undoubtedly delay natural succession from pasture to forest (Sutton and Stone Jr. 1974). Several Hylobius on the other hand may actually hasten successional trends by eliminating pioneer pines. The ecological impact of those root feeders involved in complex diseases, may be significant, but also remains undocumented.

PREVENTION AND CONTROL

Undoubtedly, many root insect problems go undetected or are misdiagnosed. The activities of these insects remain hidden until above ground plant parts become symptomatic. Unless the plant starts leaning or falls over, these symptoms unfortunately tend to be rather non-descript, often mimicking those of blights, wilts, root rots, damping-off, drought or other agents. As a result, the lower trunk and root collar region may need to be investigated for constrictions, frass, pitch tubes, and resin-soaked soil, or the plant pulled or excavated to examine the plant root for the presence of insects or their signs.

Periodic sampling of population densities, especially in cyclic species, can be helpful in making control decisions before the damage has been suffered, but few critical densities have been determined for root insects. For scarabs, they are generally in the range from 5-20 grubs/m^2 (Sutton and Stone Jr. 1974). More specifically, Fowler and Wilson (1971a) indicated the need for control in red pine plantations at grub densitities of less than 0.25 grubs/ft^2, allowing for a maximum acceptable seedling mortality of 20%. In fraser fir Christmas tree plantations, 10 white grubs/m^2 are considered the economic threshold (Kard and Hain 1987), a level which is also critical in grass sod. An average of only three or four larval H. radicis per tree represent a "moderate to heavy population" (Wilson and Schmiege 1965).

Because sampling root insects is labor-intensive and often inaccurate, recent efforts have concentrated on attempts to monitor adults of various beetles by using baited traps with ethanol and turpentine (Fatzinger 1985; Hunt and Raffa 1989). The development of behavioral attractants to predict weevil damage continues to be investigated here and in Europe.

Chemical control

Pest control is usually indicated after a problem has been diagnosed and economic thresholds have been reached. A great many insecticides including arsenicals, cyanides and several chlorinated hydrocarbons were previously employed against root feeders (MacAloney 1940; Finnegan and Stewart 1962; Fowler and Wilson 1971b, 1974). Generally, these have met with greater success in nurseries than in the field, where they often failed to meet economic criteria. Organophosphates and carbamates such as diazinon, carbofuran and trichlorfon are now recommended against white grubs (Pike et al. 1977), but are restricted to very specialized uses. As different species of these grubs tend to be active at different times in the root feeding zone, multiple applications and supplemental controls may be needed though (Kard and Hain 1987).

Biological Control

Little is known about parasites and predators of root feeding insects (Sutton and Stone Jr. 1974), slightly more so about entomopathogens. Microbial control had been suggested as early as 1869, when Riley proposed the field use of two fungi which he had observed as killers of white grubs. Muscardine fungi are known to be effective natural controls of many soil-inhabiting insects including cicadas (Katsura and Johnson 1937), white grubs and weevils (Schabel 1976), but require more field testing under North American conditions. Milky disease, a bacteriosis which had been very effective against turf grubs of the Japanese beetle, Popillia japonica, unfortunately proved less successful against other scarabs (Stone and Schwardt 1943). Lately, however, promising results were obtained in preliminary trials with entomopathogenic nematodes. Heterorhabditis heliothidis was applied with some success against O. ovatus and O. sulcatus on potted lodgepole pine and Douglas fir seedlings outdoors and in the greenhouse (Rutherford et al. 1987). Strains of the same species of nematode and of Steinernema feltiae, gave somewhat variable but still encouraging results, when used against white grubs infesting pastureland scheduled for Christmas tree planting (Kard et al. 1988). Thus, research concerning biocontrol is likely to intensify during the next few years.

Silvicultural control

While chemical and biological controls are probably most feasible in high value nurseries and Christmas tree plantations, various cultural procedures have been recommended for general field use, most of them in conjunction with site amelioration efforts, species considerations and timing aspects.

In selecting nursery sites, attention needs to be given to the potential of subsequent damage by root maggots, white grubs and Otiorhynchus weevils. The maggots tend to be most damaging on cold, wet, organic soils, whereas the weevil shares the habit of white grubs to build up on idle sites. In dealing with the latter, site preparation is often indispensable in converting grasslands to forest use. Just eliminating alternate food sources such as grass, will however not suffice, as grubs may then be forced to give their exclusive attention to tree roots (Sutton and Stone 1974), i.e. site preparation should go hand in hand with the use of insecticides or biocontrols, to actually reduce grub levels.

In the case of H. rhizophagus, N and N+P treatments in established plantations seemed to drastically reduce rates of impact by this insect (Goyer and Benjamin 1972). Since this weevil together with H. aliradicis and H. radicis tends to be most damaging in low vigor plantations, those sites might generally benefit from fertilizer applications if such treatment is economically justified. Pruning of lower branches in conjunction with duff or soil treatments around the tree base sufficiently altered habitat conditions for H. radicis to reduce larval populations for at least one year (Wilson 1967). Full stocking and proper planting depth (i.e. not providing too long a root collar) are also credited with reducing infestation levels with H. radicis (Wilson and Schmiege 1965).

White grubs and the three species of Hylobius just mentioned, also have a propensity for more serious damage, where highly preferred hosts such as the exotic Scots, Austrian pines and larches (Finnegan and Stewart 1962; Sutton and Stone Jr. 1974) are prevalent, or where native pines, especially red and jack pine are grown in mix (Kearby and Benjamin 1969). White spruce were determined to be considerably less susceptible to white grubs than some other conifers (Sutton and Stone Jr. 1974).

Simply by delaying or otherwise manipulating certain management routines, growth impact by several rootfeeders is also claimed to be reduceable.

At one time, it was found practical to transfer seedlings from the nursery bed into temporary refrigeration, just after the soil thaw, i.e. before larvae of Otiorhynchus would become active (MacAloney 1940). In areas where white grub populations are anticipated to be high, planting delay was recommended to small scale planters (Stone and Schwardt 1943). On high risk sites for black-stain root disease, pre-commercial thinnings are discouraged, because this practice may significantly increase the abundance of insect vectors, which can create infection courts and transmit the disease on roots and root collars of crop trees for 1-2 years after pre-commercial thinning.

Thinning if conducted in risk areas, should only take place after the peak beetle flight in May (Witcosky and Schowalter 1986).

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RATIONALIZING THE CONTROL OF MAJOR INSECT PESTS IN AFRICA SUB-REGION.

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SUMMARY

A compendium of major forest insects in Africa sub-Region is presented with the view to establishing priorities, articulating research efforts at regional level, as well as harmonizing the control of such pests effectively.

INTRODUCTION

Africa sub-region covers an approximate area of $11,600m^2$ which is about 36% of the land area of the world. It is thus obvious that owing to language barrier as well constraints in time and space, it would be difficult to cover in great detail all aspects of insect pest problems of the sub-region. There is no doubt however that as re-forestation and afforestation programmes expand, an awareness instigated because of the threat of drought and desert encroachment, insect pest problems assume even more threatening dimensions.

It is for the above reason that efforts at solving pest problems should be coordinated at best globally, but in practical terms, at least regionally. This proposition was in fact part of the resolution during the second FAO/IUFRO World Technical Consultation on Diseases and Insects held in India in 1975. Akanbi (1986) also emphasized the need to intensify regionalized research efforts in studies and control of pests This is where the present effort of WP S2.07.07 becomes relevant as recently presented by Nair (1988)

This paper thus attempts to collate pest problems as they occur in Africa sub-region in order to focus attention and action to identify priorities and coordinate research efforts at regional level in order to rationalize their control.

MAJOR INSECT PEST PROBLEMS

A proforma for collating information as suggested by Nair (pers. comm.) has been used but with modifications. Information was collected from various countries of the sub-region although responses were received from less than half of the total area.

Natural Forest

From all indications, it appears much less emphasis is at present given to scientific investigation in natural forests in this region. As a matter of fact, apart from the reserves and parks, much of the natural forests have disappeared in Africa. In the relatively small natural forests occuring as at present, serious insect pest problems are either non-existent or are un-noticed. In any event, they are less significant as excellent biological equilibrium appears to be in force. This situation thus restricts all research activities in the natural forests to inventory, dynamics and vegetation management

Plantations

Unlike the natural forests, total lack of the much needed biological balance has left an array of insect pests within plantations in Africa The situation has been aggravated because of silvicultural practices which lay emphasis on mono-culture rather than multi-culture. A table showing some of the serious insect pest problems using the proforma has been prepared for discussion during presentation. This table indicates African countries where the respective insects occur, the nature and degree of damage, extent of affected area, method of control currently practiced, and efforts on research. Indigenous and exotic tree species in both natural forests and plantations are included as well as felled lumber.

DISCUSSION AND CONCLUSION

From available information, a few insect pests deserve priority attention at multi-national level.

Prominent among these are *Hypsipyla* and *Phytolyma* spp. This inference is based on parameters such as the value of the host trees, the injury caused, the spread of infestation within the continent and the extent or degree of damage in each country. Other pests are *Epicerura pulverulenta*, *Dicledophlebia*, *Apion*, *Aonidiella*, *Plagiostripus*, *Ganometa*, *Theumetopoae* and the ubiquitous *Zonocerus variegatus*. The Scolytids and Platypodids (pin hole borers) and the Bostrychidae and Lyctidae (powder post beetles) are the most important and common wood insects in the tropics which also deserve multi-national cooperation.

It is obvious that apart from the need for the knowledge of the bionomics of these pests, much less has been done on their control. There is therefore the urgent need for collaborative study with the view to devising sound IPM strategies which would avoid the unwarranted use of chemical pesticides in order to protect both the environment and the forest ecosystem.

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PRIORITIES IN FOREST ENTOMOLOGICAL RESEARCH IN PAKISTAN

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SUMMARY

Covering only 5.4% of the area under forests, Pakistan comprises of conifers, scrubs, irrigated plantations, riverain, and coastal forests from himalayas to the sea coast. Being a sub-tropical country major part lies under arid sub-tropical and tropical thorn forest in the south while sub-tropical pine, dry and moist temperate and alpine steppic forests in the north.

Numerous pest insects exist in all forest types and climatic zones but defoliators and borers of living trees and felled wood are more destructive. Lepidopterous caterpillars on *Dalbergia sissoo*, *Acacia nilotica*, *Populus* spp, *Pinus roxburghii*, *Pinus wallichiana* and *Quercus dilatata* are of serious concern.

Cerambycid tree borers and buprestid bark beetles cause deformity, growth losses and mortality of *Populus* spp, *Platanus orientalis*, *Juglans regia* etc and a lepidopterous caterpillar spoils top shoots of *Salmalia malabarica* to cause forking and deterioration of timber.

Powder post beetles and termites are very serious pests but are being taken care of by application of Dieldrin which needs to be replaced being a human hazard.

Keywords: Forest pests, Pakistan priorities

INTRODUCTION

Situated between 24° and 37° N latitudes and 61° and 75° E longitudes Pakistan is a sub-tropical country with widely veried climate. Summers being hot and dry with temperature soaring upto 50° C in south and freezing winters in western and northern parts. Monsoons from the Arabian Sea bring rain during July to September varying from 100 mm to over 1500 mm.

Stretching from Arabian sea northwards across the Thar desert in Sind through Indus Valley to Himalayas, the landscape presents constrasting features. The forest types include sub-alpine scrubs, alpine dry steppe, dry temperate coniferous, himalayan moist temperate and sub-tropical pine in the northern mountains and arid sub-tropical, tropical thorn and mangrove in the south.

Out of 87.81 million ha land of the country 10.1 million ha are under forest which includes 6.1 million ha of rangelands. The actual forest area is 4.7 million ha which form 5.4% of the total area of Pakistan. Forest types comprise of 41.3% conifers, 35.9% scrub, 8.3% irrigated plantations, 6.2% riverine and 7.3% coastal forest. Such a small area under forest can hardly meet the requirements but if this meagre resource is further degraded by pest-insects the situation becomes alarming.

There are numerous insect pest problems in the forests, some occuring occasionally others of continuous nature. Most important of these, mainly the foliage feeders, shoot and stem borers and despoilers of forest-produce are being enumerated.

MAJOR INSECT PEST PROBLEMS

Natural Forest

Sl. No.	Tree species, family	Insect pest with family, order	Nature of damage	Extent of affected area ha.	Control practised	Current res. Yes/No
1	2	3	4	5	6	7
1.	Pinus wallichiana (Pinaceae)	Biston regalis (Geometridae, Lepidop)	Defoliation, kills trees.	4,000	Mechanicobiological.	No
2.	Pinus roxburghii (Pinaceae)	Cryptothelea crameri (Psychidae Lepidop)	-do-	50,000	Collection of bagworm and release of parasites	Yes
3.	-do-	Elkneria (Dasychira) aff. mulleri (Lymantriidae Lepidop)	-do-	15,000	Biological, release of parasites.	No

1	2	3	4	5	6	7
4.	Quercus dilatata (Fagaceae) Berberis lycium (Berberdaceae).	Hairy caterpiller (Lymantriidae, Lepidop).	-do-	4,500	Spraying of tree based colonies.	Yes
5.	Platanus orientalis (Platanaceae) Alnus nidita (Betulaceae)	Anomala spp (Rutelidae Coleo).	Defoliation cause growth losses.	Widely spread in hilly areas.	None	No

P l a n t a t i o n s

Area 233,000 ha : 1. Native species. Dalbergia sissoo Acacia nilotica

2. Exotic species. Populus spp.

1.	Dalbergia sissoo (Papilionaceae)	Plecoptera reflexa (Lep. Noctuidae)	Defoliation, growth loss upto 60%.	0.14 million	Spray of nurseries.	No
2.	Populus spp (Salicaceae)	Apriona cinerea Aeolesthes sarta (Coleo. Cerambycidae)	Stem borer cause 40-50% wood loss.	Large linear and compact blocks on farmland and state forests.	Insecticidal and microbial treatment.	Yes
3.	-do-	Melanophila picta (Buprestidae Colop.)	Bark borer, cause upto 35% tree mortality.	-do-	Chemical treatment	No
4.	Populus spp (Salicaceae)	Ichthyura anastomosis (Notodontidae, Lepidop)	Defoliation, 30-50% growth loss.	-do-	Microbial insecticidal spray.	No

1	2	3	4	5	6	7
5.	Acacia nilotica (Mimosaceae)	Euproctis lunata (Lymantriidae Lep.)	Defoliation cause growth loss and young plants mortality.	0.25 million	None	Yes
6.	Salmalia malabarica (Bombacaceae)	Tonica niviferana (Oecophoridae, Lepi.)	Shoot borer cause forking & growth loss.	1000	Repellent sprays	No
		Forest Produce				
1.	Fuelwood	Sinoxylon spp. (Bostrichidae, Coleop)	Destroy 40-50% fuelwood produced.	16 M m^3 stacked	Spray with dieldrin	Yes
2.	All woods in use and storage.	Termites	Destroy 10 to 50% wood used in buildings.	-	Chemical treatment	Yes
3.	Pinus gerardiana (Pinaceae)	Dioryctria abietella (Pyralidae, Lepidop)	Edible Chalgoza seed is destroyed.	-	Mechanical measures	No
4.	Pinus spp wood.	Buprestids scolytids.	Wood borer	-	Chemical treatment	No
5.	Almost all woods.	Cerambycids	Borer of wood in use and in storage	-	-do-	No.

PRIORITIES IN RESEARCH

Natural stands of pines, oak, alder and chinar in the hills and poplars, *Dalbergia sissoo* and *Acacia nilotica* in the plantations are subject to severe damage by foliage feeders, shoot and stem borers and despoilers of forest produce. A large geometrid *Biston regalis* Moore on blue pine, a bagworm *Cryptothelia crameri* Westw. and a hairy caterpillar *Elkneria (Dasychira)* sp. on chir pine are noxious defoliators of conifers. A noctuid caterpillar *Plecoptera reflexa* Guen. on shisham, a notodontid *Ichthyura anastomosis* on poplars, pyralid hairy caterpillars *Euproctis* spp. on babul and a lymantriid caterpillar on oak are most serious leaf pests of broad leaved trees in Pakistan.

Buprestid bark borers and cerambycid tree borers take a heavy toll of trees causing deformity, growth losses and outright mortality of poplars, semul, chinar and walnut etc. These borers being concealed feeders are very difficult to kill. Research efforts in the past have revealed some useful data on the biological complex of some of these but lot more remains to be done on various aspects before some effective measures could be developed against each. Pesticidal applications are not only difficult but also less effective, uneconomical and unsafe for the environment. Introduction of biocontrol agents particularly the application of microbes and augmentation of macro parasites and predators may bring about desired results.

Outbreaks of defoliating insects usually depend on naturally occurring climatic and physical changes which disturb the biological complex of the area. Large scale pesticidal sprays or introduction, suppression or augmentation of any plant or animal species also upsets the biotic equilibrium. Many a time use of toxicants to suppress obnoxious insect pests in a disturbed equilibrium aggravates the situation further by upsetting the other components of the environment and creating new pest problems.

The pest control in forests, therefore, needs more careful planning based on thorough knowledge of ecology of plant and animal components, their inter-relationships and possible repercussions of pest control measures to be adopted.

To minitor our key pests, their natural enemies and keenly evaluate their interaction for timely corrective measures based on their detailed ecological studies is of high import. To keep close watch over the potential pests and formulate preventive measures to avoid any major change in their biotic equilibrium is equally important. In the event of an outbreak of a pest resetting the disturbed balance is essential by careful study of the causitive factors and appliction of multiprong measures that are economical, safer and quicker.

The fuelwood produced in the plantation and all types of timber in use and in storage is being protected from powder post beetles and termites by application of Dieldrin, a cyclodiene insecticide, which has been banned for use being dangerous to human health. Suitable substitute for Dieldrin is direly needed to avoid heavy losses to our meagre wood resource.

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PRIORITIES FOR FOREST INSECT RESEARCH IN THAILAND

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SUMMARY

Forest insect pests of natural forests, plantations, and fell timber are listed in priorities on which research is critically needed in Thailand. The most important insects are furnished with information on research and activities have been carried out in the country.

Keywords: insect pests, research priorities.

INTRODUCTION

Today Thailand faces serious problems due to excessive deforestation. This situation can be attributed mainly to the ever-increasing demand for timber and the expansion of agriculture usage of land. As a result, forests now occupy only only 28% of the total land area (Anonymous 1989). To redress this situation the Government is endeavouring to increase forest area to 40% by discontinuing logging concessions and encouraging reforestation. However, with more forest plantations being established there will be an inevitable increase in pest and disease problems.

Under severely limited manpower and inadequate budget, research in forest entomology is able to make only marginal progress, and very often control mechanisms and eradication practises are introduced before studies of the insects are possible. Nevertheless, regardless of the above constraints, and in a situation where many new tree species are continually being planted, entomologists are automatically assumed to be able to cope with all the problems that inevitably arise. Problems are necessarily tackled on a first come, first served basis, making it virtually impossible for long-term research on important pests to be undertaken. Damage assessment and information on the status of pests are inadequate, and specialization of scientists is lacking due to inferior professional training.

The following text furnishes information on the more important forest insects in Thailand on which research is critically needed. Judging by the literature emanating from the many meetings of tropical forest entomologists in the past, many countries in the tropical region share the same, or at least, similar insect problems. Since each country is now providing details of their priority needs, it is hoped that, resulting from this 19th IUFRO World Congress, it will be possible for countries to group themselves together for joint cooperation in solving their problems and working together for mutual benefit.

Information on Forest Types and Area

1. Country area : 513,115 sq. km.
2. Natural forest
    Area (whole country) : 15.66 million ha[1] (156,600 sq. km.)
    Major forest type[1] : Mixed deciduous forest = 43.33%
    Tropical rain forest = 21.67%
    Dry dipterocarp forest = 31.20%
2. Plantations
    Total area[2] : 494,735 ha.
        Teak : 118,960 ha.
        Pinus spp. : 84,861 ha.
        Eucalyptus spp. : 25,172 ha.
        Gmelina arborea : 20,935 ha.
        Rhizophora spp. : 7,287 ha.

RESEARCH PRIORITY

The following tables list insect pests of tree species in plantations, natural forests and felled timbers. The tree species are listed in order of economic significance to the country as well as the corresponding importance/prevalence of the pests.

Insect Pests of Plantations

In Table 1, Insect Pests of Plantations of Native Species, teak receives first priority due to its high value and increasing scarcity. Damage from teak beehole borer obviously reduces the quality of the wood and the value of converted timber. Large-scale planting is implemented throughout the country each year, but only those plantations established in the north are invariably affected by this insect. Research on the teak beehole borer is underway with the cooperation of the Japanese Government through Japan International Cooperation Agency (JICA). A long-term research program aimed at controlling this insect was developed by a Japanese-provided expert. The program provides biological and tactical research in many areas.

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[1] Yearly Report 1982. Planning Division, Royal Forest Department, Thailand.
[2] Yearly Report 1988. Planning Division, Royal Forest Department, Thailand.

Unlike the beehole borer, the teak defoliators, *Hyblaea puera* and *Eutectona machaeralis*, are widely distributed throughout the country. These pests are easily controlled by the application of *Bacillus thuringiensis* Berliner. The provision of adequate manpower and finance would minimise the significance of these defoliator. However, research is being undertaken on the natural mortality of this insect, as well as the intensity of damage in different areas. Insects affecting the flower and fruit of teak become very important when seed production is critically decreased. With the limited funds available, chemical application is carried out in only one orchard at present, and further research is needed to achieve a more effective control program.

Gmelina arborea, which was planted in many parts of the country because of its superlative growth, is no longer used for industrial plantations. Most *Gmelina* plantations were destroyed by the three insects listed in Table 1, and only a few small plantations remain. At present, *Gmelina* is planted in certain specific places such as watershed area.

Insect Pests of Exotic Species

Thailand has introduced many exotic fast-growing tree species in recent years. Of these, *Acacia auriculiformis* is particularly vulnerable to damage from insect pests. Breakage of stem and branch is especially noticeable in dry years and in arid conditions. Sanitation is practised in the damage site, but with increasing plantation area, a better method must be devised to prevent the spread and growth of the insect population.

Eucalyptus camaldulensis is now popular for industrial plantations for paper pulp industry. Many pests of eucalyptus have been identified (Hutacharern et al. 1989) but none of them cause substantially damage. However, the pests of eucalyptus listed in Table 2 are potential threat and could be significantly so in the future.

The epidemic of leucaena psyllid, *Heteropsylla cubana* Crawford, which broke out amongst *Leucaena leucocephala* species in 1986 (Yantasath and Watanakul 1987) caused a great deal of concern. Many leucaena plantations and some nurseries were defoliated during the dry season but, fortunately, the plants recovered. Control of this lice is not feasible in forest land, although with the added cost-benefit value factor in agricultural land, control becomes more practicable. The population of this psyllid appears to have subsided and it is considered a relatively harmless insect in forestry compared to other pests. Also, the Leucaena plant is not an indispensable species in forestry ; it can be substituted by other fast-growing species, with at least equal if not greater benefit, if the leucaena psyllid becomes too much of a problem.

Insect of Natural Forests

Surveillance of forest insects in natural forests is inadequate and, consequently, the status of pests is not known and not documented. This unsatisfactory situation is the result of insufficient forest entomologist in the Royal Forest Department. The list of insects at Table 3 represents only an estimation by the senior forest entomologist in Thailand based on his experience (pers. comm. Chaiglom, D.).

Special emphasis should be given to *Cedrela* and *Swietenia* which are highly susceptible to infestation by the shoot borer, *Hypsipyla robusta*, in the natural forest. These tree species produce superb quality wood, are enormously valuable, and it is disappointing that experiments to establish pure plantations of *Cedrela* and *Swietenia* in Thailand have invariably failed. It is observed that trees planted close to their natural habitat are likely to suffer from the shoot borer for at least the first five years. However, limited numbers of commercially-sized Meliaceae are sometimes found in natural forests mixed with numerous other tree species. Where such diversity of species occurs, the borer is suppressed and maintained in the mixed deciduous forest.

In view of the rapid depletion of the natural environment for the two species, and to facilitate more successful planting of these native species, a research programme on this subject should be brought to attention. Many researches were conducted on this insect in South America and many of them were documented by Grijpma (1974). With the benefit of such informative work and the support and interest of an international organization to conduct specific research in Thailand, it is certain that *Cedrela* and *Swietenia* plantations could be established and would prove extremely beneficial to the country.

Insect Pests of Felled Timbers

The priority of the insects in Table 4 has been determined on the basis of their prevalence in the country. Those associated with bamboo, therefore, must rate highest due to the wide use and enormous daily consumption of bamboo, particularly among local people. Due to the short usage span of the wood, insect control is not normally practised. Insecticidal treatment only becomes a practical proposition for exporting materials in large-scale industries.

In wood-based industries with the depletion of traditional hardwood species, rubberwood, *Hevea brasiliensis* has become exceptionally popular in the construction industry and for the manufacture of furniture due to its low cost and plentiful supply. Fierce competition in the market for such products has force preservation to be regularly practised in the rubberwood industries. Current researches focus on the testing of new products for better and more effective control, as well as investigating other control methods.

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Table 1 : Insect pests of plantations of native species

Tree species	Pest identity	Nature of damage	Area affected	Control practice	Current research
1. *Tectona grandis* (area in 1982 = 118,960 ha)	*Xyleutes ceramicus*	Trunk boring, reduce quality and value	20,000 ha	Application of *Bacillus thuringiensis*	Yes
	Hyblaea puera *Eutectona machaeralis*	Defoliation, growth reduction	100,000 ha	Application of *B. thuringiensis*	Yes
	Mylabris phalerata *Machaerota elegans*	Inflorescence feeding reduce >80% of seed production	20,000 ha	Insecticidal treatment	No
	Dihammus cervinus	Trunk girdling, cause breakage of trunk of saplings	1,000 ha	Nil	No
2. *Pinus kesiya* *P. merkusii* area in 1982 = 64,861 ha	*Dioryctria abietella* *D. sylvestrella* *Petrova salweenensis*	Shoot boring and cone feeding, causes bushy and forking of the affected tree and cone drop	10% shoot damage of plantation in Northern provinces 5% cone drop	Nil	No
	Nesodiprion biremis *Diprion hutacharernae*	Defoliation	scatter	Nil (Naturally controlled)	No
3. *Dalbergia cochinchinensis*	*Threnetica lacrymans*	Trunk borer	1,800 ha	Nil	No
4. Mangrove species *Rhizophora apiculata* *R. mucronata* *Bruguiera cylindrica* area in 1982 = 7,287 ha	*Cleora injectaria*	Defoliation, growth reduction		Nil	No
	Poecilips fallax	Pod feeding, reduces seedling production		Early planting to avoid seed storage	No
	Unidentified Pyralid	same as above		Nil	No

Table 1 : Insect pests of plantations of native species (Cont.)

Tree species	Pest identity	Nature of damage	Area affected	Control practice	Current research
8. Gmelina arborea (area in 1982 = 20,[illegible] ha)	Tingis beesoni	Sap sucking, causes defoliation and mortality occurs in arid zone	20,000 ha	Insecticidal treatment	No
	Glenea indiana	Trunk borer, mortality occurs in severe case especially in moisted area	20,000 ha	Insecticidal treatment	No
	Calopepla leayana	Defoliation In epidemic stage shoots and green branches are also destroyed	20,000 ha	Insecticidal treatment	No

Table 2 : Insect pests of plantations of exotic species

Tree species	Pest identity	Nature of damage	Area affected	Control practice	Current research
1. Acacia auriculiformis	Sinoxylon anale Lesne Sinoxylon sp.	Branch and twig girdling, damage is severe on one year old tree	800 ha	Sanitation	No
2. Eucalyptus spp.	Zeuzera coffeae	Stem boring, breakage of stem occur mostly on one year old tree	800 ha	Nil	No
	Termite	Wilting and mortality occur in 1-2 year old trees	100 ha	Soil insecticide treatment	No
3. Leucaena leucocephala	Heteropsylla cubana	Defoliation reduces growth and causes mortality in severe condition	2,000 ha	Changing to resistant species	Yes

Table 3 : Insect pests of natural forest

Tree species	Pest identity	Nature of damage	Area affected	Control practice	Current research
1. *Tectona grandis*	*Xyleutes ceramicus*	Trunk boring, reduce quality and value	1,000 ha	Nil	Yes
	Hyblaea puera *Eutectona machaeralis*	Defoliation, retarding of growth rate	10,000 ha	Nil	Yes
	Mylabris phalerata *Mechaerota elegans*	Inflorescence feeding reduce <50% of seed production	10,000 ha	Nil	No
	Dihammus cirvinus	Trunk girdling, cause breakage of trunk of saplings	1,000 ha	Nil	No
2. *Avicenia alba*	*Hyblaea puera*	Defoliation	1,000 ha	Nil	No
3. *Rhizophora* spp.	*Cleora injectaria*	Defoliation	1,000 ha	Nil	No
4. *Pinus merkusii* *P. kesiya*	*Dioryctria abietella* *D. sylvestrella*	Shoot and cone boring	1,000 ha	Nil	No

Table 4 : Insect pests of felled timbers

Material (species)	Pest identity	Nature of damage	Control practice	Current research
1. Bamboo	*Dinoderus minutus* *Heterobostrichus aequalis* *Minthea rugicollis* *Sinoxylon anale*	Wood boring Wood boring Wood boring Wood boring	Ponding, insecticidal treatment	Yes
2. *Hevea brasiliensis*	*Heterobostrichus aequalis* *Heterobostrichus unicornis* *Minthea rugicollis* *Sinoxylon anale* *Xylothrips flavipes*	Wood boring Wood boring Wood boring Wood boring Wood boring	*Log* Ponding, Insecticidal treatment *Sawn Timber* Insecticidal treatment, pressure treatment, dip diffusion	Yes
3. *Pinus* spp.	*Dorysthenes walkeri* *Ips acuminatus* *Ips sexdentatus* *Platypus* spp. *Sipalus granulata*	Wood boring Bark boring and fungus carrier Wood boring Wood boring	*Log* Water spray, ponding, insecticidal treatment *Sawn Timber* Insecticidal treatment, pressue treatment, dip diffusion	Yes

MAJOR INSECT PEST PROBLEMS

COUNTRY: TANZANIA

REGIONS: ALL

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1. INTRODUCTION:

Tanzania is quite a sizeable country with an area of 940,000 square kilometres. The population is 22.5 million growing at the rate of 2.8% per annum. About 80% of the population is rural, living in about 8,000 villages. Agriculture is the main source of economy providing 40 to 50% of GNP, 80% of exports and 80% of employment.

Forests and woodland occupy about 44 million hectares which is distributed into 1,400,000 hectares natural forests, 80,000 hectares mangrove forests and 42,891 hectares woodlands. About 13,024,000 hectares have been gazetted for production and catchment purposes. Within the forest reserves there are several plantations with an area of about 80,000 hectares. The plantations were established by the Germans in early 1900's after exploiting parts of the natural forests for construction timber. They started trials of Tectona grandis, Pinus radiata and Pinus patula.

Then from 1950's/to present time large-scale industrial plantations were established bringing to total area of 80,000 hectares. Other tree species were also introduced and included Eucalyptus spp; Cedar, podo, Cypress spp, Olea africana and Grevilled robusta.

In order to overcome the rate of deforestation - which is about 300,000 - 400,000 hectares per year tree plantations were established in the villages by individuals, communal efforts, schools, churches, and various institutions. The plantations are now scattered all over the country. Through these efforts about 70,000 hectares have been planted. Tree species in use are Acacia albida, Eucalyptus spp, Cassia spp, Grevillea robusta and Cupressus Lusitanica.

2. OVERVIEW OF MAJOR PEST PROBLEMS:

In general exotic species in mono cultures like industrial plantations and village woodlots are vulnerable to large - scale insect attacks. However, up to 1987 this country has not experienced a major insect outbreak. Few incidences of insect pests have been reported in some of the conifer plantations. An insect survey was carried out in all the plantations and the table below summarizes the common insect pests. They have been grouped into three major categories which are - Defoliators, borers and suckers.

PLANTATIONS - EXOTIC SPECIES

NO.	TREE SPECIES WITH FAMILY	PEST IDENTITY	NATURE OF DAMAGE	EXTENT OF AFFECTED AREA	CONTROL PRACTISED	CURRENT RESEARCH
A. DEFOLIATORS:						
1.	Pines	Agrotis segetum	Leaves	NOT KNOWN	NIL	BIOLOGICAL CONTROL
2.	Pines	Euxoe segetis	Leaves	"	"	" "
3.	Pines	Polia agrotid	Leaves	"	"	" "
4.	Pines	Phodogastria bulso	Leaves	"	"	" "
5.	Pines	Scirartia clara	Leaves	"	"	" "
6.	Pines	Angelika tyrrhea	Leaves	"	"	" "
7.	Pines	Bunaea alcinoe	Leaves	"	"	" "
8.	Pines and Cypress	Gynanisa maia	Leaves	"	"	" "
9.	Pines	Nudaurelia dione	Leaves	"	"	" "
10.	Pines	Nudaurelia quenzii	Leaves	"	"	" "
11.	Pines	Nudaurelia oubie	Leaves	"	"	" "
12.	Pines	Xanthisthisa tarsispina	Leaves	"	"	" "

NO.	TREE SPECIES WITH FAMILY	PEST IDENTITY	NATURE OF DAMAGE	EXTENT OF AFFECTED	CONTROL PRACTISED	CURRENT RESEARCH
13.	Pines and Eucalyptus	Gonometa podocarpi	Leaves	NOT KNOWN	NIL	BIOLOGICAL CONTROL
14.	Pines and Eucalypts	Lechriolepis basirufa	Leaves	"	"	" "
15.	Pines and Eucalypts	Ctnarytaina eucalypts	Leaves	"	"	" "
16.	Pines and Eucalypts	Nadiasa aculeatum	Leaves	"	"	" "
17.	Pines and Eucalypts	Nadiasa concavum	Leaves	"	"	" "
18.	Pines and Eucalypts	Nadiasa cuneatum	Leaves	"	"	" "
19.	Pines and Eucalypts	Nadiasa diplocyma	Leaves	"	"	" "
20.	Pines	Pachipasa davisa	Leaves	"	"	" "
21.	Pines	Pachipasa drucei	Leaves	"	"	" "
22.	Pines	Pachypasa scericeofasciata	Leaves	"	"	" "
23.	Pines	Pachypasa subfasciata	Leaves	"	"	" "
24.	Pines	Philothrma clara	Leaves	"	"	" "

25.	Pines	Pseudometa affinis	Leaves	NOT KNOWN	BIOLOGICAL CONTROL
26.	Pines	Schausina affinis	Leaves	"	" "
27.	Pines and radiata	Dasychira gorgiana	Leaves	"	" "
28.	Pines and cypress	Orgia basalis	Leaves	"	" "
29.	Pines and cypress	Orgia hopkins	Leaves	"	" "
30.	Pines and cypress	Apion sp.	Leaves	"	" "
31.	Pines	Cassida parummaculata	Leaves	"	" "
32.	Pines	Cassida picturata	Leaves	"	" "
33.	Pines	Cassida punctata	Leaves	"	" "
34.	Pines	Diplognatha gagetes	Leaves	"	" "
35.	Pines	Gametis sp.	Leaves	"	" "
36.	Pines	Gnathocera truncata	Leaves	"	" "
37.	Pines	Gnathocera sp.	Leaves	"	" "
38.	Pines	Heteropseudinca viribilis	Leaves	"	" "
39.	Pines	Grathocera sp.	Leaves	"	" "
40.	Pines	Heteropseudinca wentzel	Leaves	"	" "
41.	Pines	Leucocelis elegans	Leaves	"	" "

NO.	TREE SPECIES WITH FAMILY	PEST IDENTITY	NATURE OF DAMAGE	EXTENT OF AFFECTED AREA	CONTROL PRACTISED	CURRENT RESEARCH
42.	Pines	Pachnoda impunctata	Leaves	NOT KNOWN	NIL	BIOLOGICAL CONTR
43.	Pines	Pachnoda sinuata	Leaves	"	"	" "
44.	Pines	Pachnodella impressa	Leaves	"	"	" "
45.	Pines	Porphyronata sp	Leaves	"	"	" "
46.	Pines	Stephanorrhina princeps	Leaves	"	"	" "
47.	Pines radiata	Epilachna fulvosignata	Leaves	"	"	" "
48.	Cypress	Calandra lineris	Leaves	"	"	" "
49.	Pines	Dicasticus affinis	Leaves	"	"	" "
50.	Pines	Dicasticus funicularis	Leaves	"	"	" "
51.	Pines	Entypotrachelus meyeri	Leaves	"	"	" "
52.	Pines	Entypotrachelus micans	Leaves	"	"	" "
53.	Pines	Epipedosoma undulatum	Leaves	"	"	" "
54.	Pines	Epipedosoma zanguoboycum	Leaves	"	"	" "
55.	Pines	Lixus bidentatus	Leaves	"	"	" "
56.	Pines	Idacantha suahelorum	Leaves	"		" "

NO.	TREE SPECIES WITH FAMILY	PEST IDENTITY	NATURE OF DAMAGE	EXTENT OF AFFECTED	CONTROL PRACTISED	CURRENT RESEARCH
57.	Pines	Megaleruca triloba	Leaves	"	"	"
58.	Pines	Oides collaris	Leaves	"	"	"
59.	Pines	Oides sp	Leaves	"	"	"
60.	Pines	Pachylomelina	Leaves	"	"	"
61.	Pines	Pines	Leaves	"	"	"
62.	Pines	Prosmidia conifera	Leaves	"	"	"
63.	Pines	Haltica foreigera	Leaves	"	"	"
64.	Pines	Haltica fulgens	Leaves	"	"	"
65.	Pines	Physonichis nigricollis	Leaves	"	"	"
66.	Pines	Dactylispa hirsuta	Leaves	"	"	"
67.	Pines	Dactylispa modica	Leaves	"	"	"
68.	Pines	Dicladispara nr. jeanneli	Leaves	"	"	"
69.	Pines	Chrysolagria naivashana	Leaves	"	"	"
70.	Pines	Largia purpuracens	Leaves	"	"	"
71.	Pines	Largia villosa	Leaves	"	"	"
72.	Pines	Chromothericles sp,	Leaves	"	"	"

NO.	TREE SPECIES WITH FAMILY	PEST IDENTIFY	NATURE OF DAMAGE	EXTENT OF AFFECTED AREA	CONTROL PRACTISED	CURRENT RESEARCH
73.	Pines	Crytachanthacris sp	Leaves	"	"	"
74.	Pines	Plagiotriptus pinivorus	Leaves	"	"	"
75.	Pines	Usambila modicrus	Leaves	"	"	"
76.	Pines	Veseyacris sp. nr ufipae	Leaves	"	"	"
77.	Pines	Monticolaria sp.	Leaves	"	"	"
78.	Cupressus family	Cinara cupressi	Sap sacker	Iringa, and Mbeya		
79.	Pines	Pineus pini	Sap sucker	NOT KNOWN	CHEMICAL	BIOLOGICAL CO
80.	Pines	Ptyelus grossus var abumeus	Sap sucker	"	"	"
81.	Pines	Acanthomia tomentosicola	Sap sucker	"	"	"
82.	Pines	Anoplocnemis dallasiana	Sap sucker	"	"	"
83.	Pines	Anoplocnemis curypens	Sap sucker	"	"	"
84.	Pines	Liorhyssus hyalinus	Sap sucker	"	"	"
85.	Pines	Plectopoda bicora	Sap sucker	"	"	"
86.	Pines	Sphaerocoris annuals	Sap sucker	"	"	"
87.	Pines	Sphaerocoris testuzricea	Sap succker	"	"	"

88. Pines	Coptosoma punticeps	Sap sucker	"	"	"
d. WOOD BORERS 89. Cypress	Androeme plagiata	Boring	NOT KNOWN	Preservatives	Graveyard
90. Cypress	Chlorophorus carinatus	Boring	"	Preservatives	Graveyard
91. Cypress	Oemida gahani	Boring	"	"	"
92. Pines	Phantasis gorgo	Boring	"	"	"
93. Pines	Sthenias cylindrator	Boring	"	"	"
94. Pines and cypress	Hylaster ater	Boring	"	"	"
95. Pines and cypress	Pinhole	Boring	"	"	"
96. Cypress	Termites	Boring	"	"	"

3. OUTBREAK OF CYPRESS APHID:

A set back of our village afforestation efforts occured in 1987. An aphid known as Cinara Cupress attached trees belonging to cupress family. The cypress family include tree species of Callitris, Jníperus and Widdringtonia. This typre of aphid is very new to this country. The name "Cinara cupressi" was confirmed by Mr. P.A. Brown of BUNH. The outbreak was first reported in June 1987 at Bundali Division - Ileje District - Mbeya Region. The district of Ileje borders Malawi.

4. MODE OF INFESTATION:

The aphids ruck the sap from the plant by taking away the plant food and cause damage by puncturing the plant cells. The number of aphids on 10 cm shoot could be as high as 80 and over. The signs after attack are dieback and at high population levels, death of the trees occur. It was noted that, the infested areas neemed to have little rainfall in the year 1986/87 comapred to the previous years. Hence, drought can make trees move susceptible to insect attack. Some activities in an insect may be increased by dry weather.

5. CONTROL:

In the infested areas, the number of paracites and predators recorded was rather low compared to the abundance of aphids. This could robably be due to the fact that Cinara cupressi is a new pest to this environment and adaptation of the local enemies is still taking place.

Among the natural enemies found feeding on the aphid include:-

- Syrphidae spp - Dipteva family
- Coccinellidae spp - Coleoptera family
- Chalcididae and Ichneumonidae spp - Hymenoptera family.
- Chrysopidae and Hemerobiidae spp - Nounoptera

It is anticipated athat, research on breeding and release of prospective parasites and predators as well of origin of the pest will be done.

6. BREEDING FOR RESISTANCE:

It was noted that infested trees co-exist with non infested trees in one stand. Hence some trees are resistant to aphid infestation. Therefore, the possibility of control of this pest by breeding resistant trees could be viable.

7. CHEMICAL CONTROL:

Some experiments were conducted by spraying insecticides such as Dursban, Endosulfan and sumithion. The initial results show that dying Cypress which were sprayed with insecticides were tree from the problem while the unsprayed trees were continuing dying.

ESTUDIO DEL GRADO DE INFECTACION POR SCOLYITIDAE EN MADERA CORTADA

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FDC: 453: 174.7 Pinus elliottii Engelm.: 145.7 Scolytidae

SUMMARY

This research was carried out at the Monte Alegre Farm, owved by Klabin do Paraná Agroflorestal S.A., situated in the county of Telêmaco Borba - Paranâ - Brazil, from June/85 to May/86 in homogeneous forests of *Pinus elliottii*.

Harvesting conditions were simulated during 12 months and logs kept in the forest for up to six months in order to determine the level of infestation of Scolytidae according to felling month and storage time.

It was noticed that 10 species of Scolytidae infested the wood stored inside the forest, the species *X. ferrugineus* was responsible for 77,40% of the damage caused. The older stand were more infested, and the attack was noticed after 30 days of storage in all months of the year.

Keywords: Ambrosia beetles, *X. ferrugineus, P. elliottii*

INTRODUCCION

En vários trabajos de relevamiento de la entomofauna en bosques implantados con *Pinus* spp. en el Brasil, se constantó una perfecta adaptación de la familia Scolytidae a este tipo de plantación. También se observó un crecimiento de la población a medida que el bosque envejece (Marques 1984). Estas fueron las razones que motivaron la realización del presente trabajo, que visó cuantificar el grado de infectación por Scolytidae en madera recién cortada y depositada en el interior del bosque en función del tiempo de permanencia en este.

MATERIAL Y METODOS

Caracterización del área de estudio

El estudio fue realizado en la propriedad Monte Alegre de la Klabin de Paraná Agro-Forestal S.A., en el municipio de Telêmaco Borba, Paraná, Brasil, situada en la región centro paranaense, segundo planalto, entre los meridianos 50° 21' e 50° 43' de longitud oeste y entre los paralelos 24° 03'y 24° 28' de latitud sur.

De acuerdo con la clasificación de Koeppen, referida por Maack (1968), el clima de la región pertenece al tipo "Cfb", o sea, templado húmedo con lluvias durante todo el año y verano fresco. Según la clasificación de zona de vida de Holdridge (1982) la región donde se realizó el presente estudio está situada en la formación ecológica "Bosque húmedo templado". Fueron escojidos tres rodales de *Pinus elliottii*, el primero con 7 años de edad y con apenas un raleo; el segundo con 11 años y con dos raleos realizados y el tercero de 17 años con tres raleos.

Metodologia adoptada

El estudio del grado de infectación de Scolytidae, fue realizado por medio de la observación y análisis de la madera depositada en el interior de la comunidad forestal.

a) Corte de árboles

El material leñoso fue obtenido a través del corte, desgaje, trazamiento y apilado del mismo en el bosque. Esta operación se inició en julio de 1985, prosiguiendo mensualmente hasta mayo de 1986, con la finalidad de posibilitar la infectación en todos los meses del año.

b) Depósito del material de estudio

Los árboles cortados furon trazados en pedazos con largura de 2,40 metros, siendo depositados en el local del corte, visando un periodo de permanencia máxima de 180 dias. Estos troncos fueron identificados con etiquetas, que contenian las siguientes informaciones: fecha de corte, especie forestal, número del tronco en relación a la base del árbol. El número de troncos depositados por fecha de corte varió entre 10 y 15, dando condición de aleatório al muestreo.

Colecta de la muestras

La colecta de las muestras de los troncos provenientes de los cortes mensuales, se iniciaró 30 dias después del primer corte, o sea, en julio de 1985.

De esta forma se consiguieron 6 trocos referentes a cada corte, que variaron de 30 a 180 dias de permanencia en el interior del bosque.

De cada punto de muestreo fue retirada mensualmente, aleatoriamente, un tronco y de este fueron retirados tres secciones de 20 cm. de largura, distribuidos a lo largo del tronco. La primera sección fue retirada de la extremidad más gruesa, donde se encontraba la etiqueta y la identificación, la segunda a 1/3 de la largura y la tercera a 2/3 de la largura (Figura 1).

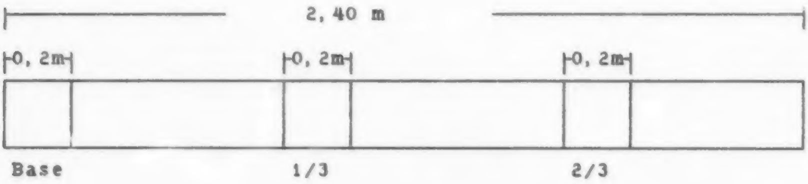

FIGURA 1. Esquema de la largura de los troncos y puntos de muestreo para análisis en laboratorio y clasificación del grado de infectación por Scolytidae. Telêmaco Borba, Paraná - 1985/86.

Avaliación de la infectación

Las muestras de madera fueron levadas al Laboratório de Protección Forestal de la Universidad Federal del Paraná para análisis de la infeotación. En el laboratório fue hecha una avaliación macroscópica del material leñoso, y en seguida se procedió a la retirada de la cáscara de las muestras. Después del descascamiento fue examinado el número de agujeros presentes en la superficie del leño, siguiendo el desdoblamiento del material leñoso con la finalidad de observar el grado de comprometimiento provocado por el "taladro ambrosia".

Fue llevado en consideración principalmente la presencia del hongo como comprometimiento màximo. Tambièn fueron identificados todos los "taladros" que estaban presentes en el interior de la madera. El grado de infectaciòn fue caracterizado en tres niveles: bajo, medio y alto, siendo los mismos subdivididos en tres subgrupos, adoptando-se el sistema de puntos para cada uno de los niveles, como se vè a seguir:

BAJO <
- 0 - Sin infectaciòn
- 1 - Galerias superficiales entre la càscara y el leño
- 2 - Galerias hasta 1 cm
- 3 - Galerias hasta 2 cm en el leño

MEDIO <
- 4 - Galerias hasta 2 cm y con hongo
- 5 - Galerias con mas de 2 cm y apenas una especie presente
- 6 - Galerias con mas de 2 cm y hongo presente

ALTO <
- 7 - Galerias con hongo y vestigio de camara pupal
- 8 - Galerias profundas con hongo en los 3 puntos de muestreo
- 9 - Galerias con hongo y señales de reinfectaciòn

RESULTADOS Y DISCUSION

En la Tabla 1, estàn relacionadas las especies que fueron encontradas infectando la madera y sus porcentajes de participaciòn. La especie *Xyleborus ferrugineus* fue la màs importante y que dispensarà mayores estudios futuros. Macedo (1975) relatò el ataque de *X. ferrugineus* a eucaliptos en el Estado de San Pablo (Brasil), afectando un nùmero considerable de plantas; examinando pedazos de *Eucalyptus* sp. recièn cortados, descascarados y apilados, constatò que estaban muy atacados por Scolytidae.

En la Tabla 2 puede ser observado el puntaje atribuido a cada muestra, lo que corresponde a la intensidad de infectaciòn. En el Àrea con siete años donde fue realizado solamente un raleo, fue observado apenas una muestra con inicio de infectaciòn durante los primeros 30 dias de permanencia de la misma en el bosque. A los 60 dias fueron observados seis muestras con infectaciòn. De 90 a 120 dias 50 % de las muestras presentaron infectaciòn y a partir de 120 dias en 83 % de las muestras se constatò la presencia de Scolytidae.

En el área con 16 años, donde ya había sido realizado tres raleos, el grado de infectación fue el mayor observado. A los 30 días de permanecer depositadas en el bosque, en cuatro muestras fue constatada la presencia de Scolytidae, a partir de 60 días 83 % ya estaban infectadas, llegando a 100 % a los 120 días.

TABLA 1. Relación de las especies encontradas infectando madera depositadas en el interior del bosque y sus respectivos porcentajes en relación al total en comunidades de *P. elliottii*. Telêmaco Borba, Paraná. 1985/1986.

Especies	% encontrados en la madera F (%)
Hypothenemus eruditus	-
Theoborus villosus	2,60
Xyleborus affinis	3,07
X. biconicus	0,10
X. brasiliensis	0,50
X. catharinensis	0,10
X. ferrugineus	77,40
X. gracilis	10,40
X. hagendorni	4,30
X. linearicollis	1,30
X. paraguayensis	0,10
Total	1 100% = (2442)

Desde el punto de vista económico, las muestras que recibieron puntaje igual o superior a seis fueron las más importantes, debido a la profundidad de las galería y a la presencia del hongo del género *Ambrosia* en las mismas. La área del primer raleo presentó hongo a partir de la tercera colecta, mientras que en las áreas del segundo y tercero raleo presentaron una muestra cada una con hongo en la segunda colecta. La presencia de hongo pasó a ser rutinera a partir de los 60 días de permanencia de las muestras en el interior del bosque.

La Figura 2 muestra el ritmo de infectación de los troncos en función del tiempo de permanencia en el interior del bosque. La área con un raleo presentó una infectación menor siguiendo la área con dos y tres raleos, siendo que esta última fue la que presentó un mayor grado de infectación. La tendencia demostrada por la curva apunta que el ritmo de infectación es el mismo para todas las comunidades, pero aumenta a medida que la plantación envejece.

TABLA 2. Grado de infectación según puntaje atribuido al daño de Scolytidae en muestras de madera depositadas en el interior de las comunidades de *P. elliottii* después del primeir raleo (1R), segundo raleo (2R) y tercer raleo (3R). Telêmaco Borba, Paraná. 1985/86.

Tiempo de permanencia en el bosque (días)		CORTES												TOTAL PUNTAJE
		1985							1986					
		J	J	A	S	O	N	D	E	F	M	A	M	
30	1R	0	0	0	0	0	0	2	0	0	0	0	0	2
	2R	0	0	0	0	0	0	0	0	3	0	0	1	4
	3R	0	0	0	0	1	0	0	0	4	2	0	1	8
60	1R	0	1	0	0	4	0	3	0	3	3	4	0	18
	2R	0	0	1	3	4	0	0	0	5	8	0	2	23
	3R	1	1	3	3	4	6	0	0	3	4	4	1	30
90	1R	0	0	4	5	0	0	0	8	1	3	0	9	30
	2R	2	3	2	5	7	4	0	9	5	6	6	2	51
	3R	0	2	6	4	4	0	3	4	9	6	9	5	52
120	1R	0	7	5	0	4	9	7	9	7	6	6	1	61
	2R	3	7	6	0	8	6	6	9	9	6	1	6	67
	3R	4	7	7	6	7	5	4	9	8	8	5	8	78
150	1R	6	8	0	4	0	4	8	9	4	4	8	8	63
	2R	4	9	0	9	0	9	9	5	6	6	8	4	69
	3R	5	8	8	3	7	9	9	9	6	4	6	6	80
	1R	0	8	3	0	4	9	9	9	3	3	9	9	66
	2R	5	7	4	9	6	7	4	9	4	9	2	7	73
	3R	6	8	8	8	9	9	4	9	9	5	0	8	83

Según Graham (1968), Moeck (1970 y 1981), Samaniego & Gara (1970) y Cade *et alii* (1970) los insectos ambrosia són atraidos por sustâncias volátiles producidas por la fermentación anaeróbica de carbohidratos de la madera durante su deteriorización. Los autores afirmaron que ésta atracción es ejercida apenas la madera entra en proceso de fermentación. La intensidad de ataque depende también del tamaño de la población en el ecosistema, lo que determina un mayor o menor poder de destrucción de la madera y de las condiciones de temperatura para acelerar el proceso de fermentación y en consecuencia la atracción. En la Figura 2 se observa que a los 30 dias de permanencia de la muestras en el bosque, para las condiciones del local del presente trabajo, la infectación fue insignificante. Esta baja infectación puede ser atribuida a las condiciones desfavorables para una fermentación rápida y a bajos niveles de población. Observandose los gráficos se nota una creciente infectación en la madera a los 60, 90 y 120 días de permanencia de las muestras en el bosque, después de esto sucede una estabilización. El aumento de la infectación es atribuido a dos factores: la reinfectación, que fue observada hasta tres generaciones, o a la llegada de un número grande de insetos ya en el primer momento. La intensidad de infectación es proporcional al tamaño de la población de insectos. En los rodales con mayor población se observó una mayor intensidad de infectación. Esta relación lleva a concluir que el número de insectos presentes en un ecosistema irá a determinar el grado de infectación.

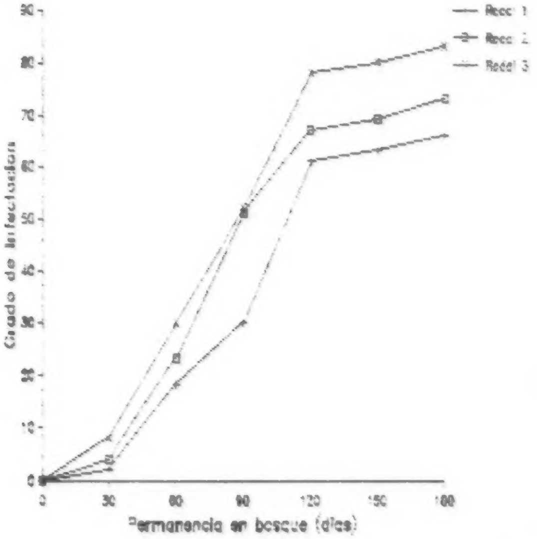

FIGURA 2. Indice de infectación por Scolytidae en madera depositada en el ecosistema forestal durante seis meses, en bosques implantados de *P. elliottii*, con tres diferentes números de raleos. Telêmaco Borba, Paraná - 1985/86.

Desde el punto de vista de daño económico se puede afirmar que para las condiciones ambientales de la región en estudio, una permanencia de hasta 30 dìas de la madera en el interior del bosque, en cualquier època del año, no ofrece riesgos de daños.

La presencia de hongos fue observado a partir de 30 dìas de permanencia en el bosque (Tabla 2), intensificandose èsta presencia despuès de los 60 dìas. Para la madera extraìda para consumo, donde la presencia del hongo no es deseable, se recomienda el deposito en el bosque por un periodo limite màximo de 60 dìas.

CONCLUSIONES

Fueron observadas 10 especies infectando madera, siendo *Xyleborus ferrugineus* la especie predominante, con 77,40 % del total del daño.

Toda madera cortada y depositada en el interior del bosque podrà ser infectada cuando el tiempo de permanencia fuere superior a 30 dìas, no habiendo excepciòn a ningùn mes del año.

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PRIORITIES IN FOREST ENTOMOLOGICAL RESEARCH IN INDIA

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SUMMARY

The insect pest problems in plantations of native and exotic tree species, natural forests and stored timber in India are prioritised and listed with brief comments on control practised if any and current research. Research needs for the country are also analysed and priorities indicated.

Key words: Insect pests, forest plantations, natural forests, India.

INTRODUCTION

Being a large country with a striking variety of climatic and edaphic conditions, the forests of India range from the low, alpine scrub to the magnificent, tall, tropical evergreen forest. Sixteen major forest types have been recognized, under four broad categories - alpine, temperate, subtropical and tropical - together covering about 64 million ha. A summary of the major forest types and area is given in Table 1. (See Lal 1989 for complete details).

Table 1: Basic information on forests of India (Million ha)

Total geographical area	:	328.8
Total Forest cover	:	64.2
Major types:		
Tropical wet evergreen	:	5.1 (8%)
Tropical semi-evergreen	:	2.6 (4.1%)
Tropical moist deciduous	:	23.7 (37%)
Tropical dry deciduous	:	18.6 (28.6%)
Sub tropical	:	6.1 (9.5%)
Temperate	:	4.5 (7%)
Alpine	:	1.8 (2.9%)
Plantations	:	4.0

Source: Lal 1989

While the alpine, temperate and subtropical forests, distributed mostly in the northern states close to the Himalayas, constitute less than 20% of the forest area, the predominant forests are tropical, with the moist deciduous and dry deciduous forests accounting for the greater part (>42 million ha). Tropical wet evergreen forests extend over 5 million ha and plantations, raised on cleared natural forests or on degraded forests, account for about 4 million ha.

PROBLEMS IN PLANTATIONS

Plantations of over 170 species have been raised in different eco-climatic regions of the country, most of them as small scale experimental plantings (Seth 1977) but at least 30 species can be recognized as important plantation species. Most species raised in plantations suffer damage from one or more serious pests (Nair 1986). Some of them like the native *Bombax malabaricum*, *Gmelina arborea* or *Ailanthus triphysa* and the exotic *Swietenia macrophylla* (mahogany) have not been favoured for plantations because of pest problems.

Thus there is difficulty in deciding the most important problems based on the species-wise extent of plantations. In addition, data on area under all species is not readily available. However, an attempt is made in Tables 2 & 3 to list the problems according to their felt seriousness.

Among plantations of native tree species, teak (*Tectona grandis*) in the southern part of India and Sal (*Shorea robusta*) in the northern part, are economically the most important. Defoliation of teak (Table 2) is an annual phenomenon throughout the teak areas in India. In Kerala State in southern India loss due to the defoliator, *Hyblaea puera*, has been estimated at 44% of the potential volume increment while the other species *Eutectona machaeralis* had little impact (Nair *et al* 1985). The latter species is considered to be more serious in other parts of India but there is little recorded information on its incidence. Much work has been done in the past on teak insects, but an effective method for their management is yet to be developed. The cerambycid borer, *Hoplocerambyx spinicornis*, causes extensive mortality and damage to sal in sporadic outbreaks and much remains to be learnt of its management in spite of fairly effective silvicultural and trap-tree methods of control now advocated. Other important plantations and their pests are listed in Table 2.

Among the exotics (Table 3), the only major pest of eucalypts, the termites has been effectively checked by use of insecticides, but there is need to develop methods for control using safer insecticides and non-chemical methods. The mahogany shoot borer, *Hypsipyla robusta*, is a constraint to cultivation of Mahogany and control methods against the insect would prove very rewarding, particularly since it is also a pest of the native *Toona ciliata*. The recently introduced *Leucaena leucocephala* has thrived well in many parts of India, but the introduced psyllid, *Heteropsylla cubana*, has posed a serious threat.

Table 2: Insect pests of plantations of native species

Tree species	Pest identity with Order & Family	Nature of damage	Area (000 ha)*	Whether control practised
Tectona grandis	1. *Hyblaea puera* (Lep., Hyblaeidae)	Defoliation, growth reduction	**1400**	No
	2. *Eutectona machaeralis* (Lep., Pyraustidae)	Defoliation with negligible damage		No
	3. *Cossus cadambae* (Lep., Cossidae)	Trunk boring, often kills trees		No
Shorea robusta	1. *Hoplocerambyx spinicornis* (Col., Cerambycidae)	Borer in live trees	20	Yes, silvicultural & trap tree
Dalbergia sissoo	1. *Plecoptera reflexa* (Lep., Noctuidae)	Defoliation	**80**	No
	2. *Dichomeris erdidantis* (Lep., Gelechiidae)	Defoliation		No
Gmelina arborea	1. *Calopepla leayana* (Col.,Chrysomelidae)	Defoliation		No
	2. *Tingis beesoni* (Hem., Tingidae)	Shoot die-back		No
Bombax malabarica	1. *Tonica niviferana* (Lep., Oecophoridae)	Shoot boring		No
	2. *Ectropis bhurmitra* (Lep., Geometridae)	Defoliation		No
Ailanthus spp.	1. *Atteva fabriciella* (Lep.,Yponomeutidae)	Top shoot webber		No
	2.*Eligma narcissus* (Lep., Noctuidae)	Defoliation		No

* Agarwala (1972)

Table 3: Insect pests of plantations of exotic tree species

Tree species	Pest identity with Order & family	Nature of damage	Area* (000 ha)	Control practised
Eucalyptus spp.	1. Termites (Iso., Termitidae)	Sapling mortality	550	Yes, Insecticidal
Swietenia macrophylla	1. *Hypsipyla robusta* (Lep., Phycitidae)	Shoot borer	-	No
Leucaena leucocephala	1. *Heteropsylla cubana* (Hom., Psyllidae)	Shoot die-back	-	Rarely, insecticidal & biological

* Agarwala (1972)

PROBLEMS IN NATURAL FORESTS

Insect pests have seldom been recognized as serious problems in natural forests in India. This is partly due to lack of adequately recorded information, although in general, natural tropical mixed forests are considered to be less pest prone than temperate forests. Natural stands of teak as well as sal (*Shorea robusta*) suffer from pests as do the plantations. Pest problems also occur in Pines and *Toona ciliata* (Table 4). Much more information needs to be gathered on pest activity in natural forests, paticularly with respect to the role of natural enemies in regulating pest populations.

PESTS OF STORED TIMBER

Bostrychid borers are the major problem in stored timber. Sapwood of most timbers and the entire stemwood of low density timbers suffer damage from a variety of borers during storage. *Sinoxylon* spp on Mango, *Bombax* and rubberwood and *Dinoderus* spp on bamboo are examples. Except the conventional preservative treatment of converted timber, no effective prophylactic treatment is available to prevent damage to timber during the pre-conversion storage period. This is a priority area for attention.

Table 4: Insect pests of natural forests

Tree species	Pest identity with Order & family	Nature of damage	Area	Control practised
Shorea robusta		(See Table 1)		
Tectona grandis		(See Table 1)		
Dalbergia sissoo		(See Table 1)		
Pinus spp.	1. *Dioryctria abietella* (Lep., Phycitidae)	Top shoot boring	-	Nil
	2. *Lebeda nobilis* (Lep., Lasiocampidae)	Defoliation	-	Nil
Toona ciliata	1. *Hypsipyla robusta* (Lep., Phycitidae)	Top shoot boring	-	-
	2. *Pagiophloeus longiclavis* (Col.,Curculionidae)	Trunk borer	-	-

CONCLUSIONS

The priorities in forest entomological research in India are obvious and have been discussed earlier by Nair (1986). Over a century since forestry research began in India we have accumulated a vast wealth of information on the variety, identity and biology of forest insects and the damage caused by them. But practical achievements in control are rare (See Tables 2,3 & 4). The major pest problems are well known. What is needed is an organised effort to address the problems, instead of individualised, fragmentary research efforts. A shift from the descriptive to analytical study, with emphasis on population phenomena is essential. For this there is a need to train a new generation of forest entomologists with adequate skills and motivation. Equally important is the necessity to make the entomologists responsible to demonstrate the effectiveness of the methods they develop. Indian forest entomological literature is replete with recommendations which have seldom been practised, and entomologists often get away with the excuse that practical demonstration and field application are routine jobs which should not tie down the researchers. Networking of research efforts with other countries having similar problems can remedy the deficiencies in attitudes, and project- specific funding with international support can sustain the interest of individual scientists in solving problems. India has enough expertise in insect taxonomy which can be shared for the benefit of other countries. Fundamental research leading towards an understanding of insect ecology in natural and man-modified ecosystems must also be promoted simultaneously.

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PERSPECTIVAS DE DESARROLLO DE LA ENTOMOLOGIA FORESTAL EN URUGUAY

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SUMMARY

Teaching, research and extension on Forest Entomology in Uruguay is diagnosed. Main limiting factor identified in research funds scarcity. General guidelines for medium-term development are also presented emphasizing the importance of international regional integration.

RESUMEN

Se realizó un diagnóstico de la enseñanza, la investigación y la extensión en el área de la Entomología Forestal para Uruguay, del cual surge que la principal limitante corresponde a escasos recursos destinados a la investigación. Además se presentan las líneas generales de una propuesta que permite a mediano plazo el desarrollo del área, resaltando la importancia de la integración regional.

La ENSEÑANZA a nivel superior en Uruguay se realiza a través de la Universidad de la República y sus dependencias (Facultades, Escuelas e Institutos).

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La formación en el área de la Entomología se lleva a cabo esencialmente en la Facultad de Agronomía mediante el curso de Entomología Básica y de Entomología Aplicada que se dictan en las distintas orientaciones contempladas en la carrera de Ingeniero Agrónomo. Dichos cursos tienden a formar al estudiante en aquellas actividades científicas o técnicas que lo habilitan para obtener en el futuro, los conocimientos adicionales necesarios y para encarar con base sólida, el estudio de situaciones o de nuevos problemas, cuando la información sobre los mismos no existe o no es fácilmente accesible. Es decir,se pretende crear en el estudiante un criterio que asociado a otras asignaturas le permitan un desempeño profesional eficiente en el futuro. No se contempla la formación de investigadores en la materia.

Por otra parte, cabe mencionar que en nuestro país la enseñanza forestal tiene apenas veintiséis años de antiguedad. Comenzó en 1963 con la aprobación de un nuevo plan de estudios en la Facultad de Agronomía que contemplaba la enseñanza forestal como orientación en el cuarto año de la carrera. En dicho curriculum, la Entomología Forestal estaba a cargo de la Cátedra de Entomología y se dictaba en carácter de cursillo. En el año 1980, se modifica el curriculum para la orientación forestal pasando a tener dos años de duración (cuarto y quinto año) y en dicha modificación la enseñanza de la Entomología Forestal forma parte del curso de Protección Forestal.

La INVESTIGACION en entomología forestal en Uruguay la realiza la Dirección Forestal del Ministerio de Ganadería,Agricultura y Pesca (MGAP) y el Departamento Forestal de la Universidad de la República - Facultad de Agronomía.

La Dirección Forestal (MGAP) está trabajando en dos proyectos:

a. Segunda lista de insectos de interés forestal
    a.1. Primera parte: Lepidoptera (finalizada)
    a.2. Segunda parte: Coleoptera (por finalizar)

b. Insectos asociados a frutos y semillas de árboles y arbustos indígenas.

El Departamento Forestal de la Facultad de Agronomía, está llevando a cabo el proyecto "Estudio de los insectos plaga del género Pinus en Uruguay", cuyos objetivos son: la detección de ataque inicial de insectos plaga y de enemigos naturales; el estudio de la dinámica poblacional, la evaluación de daños y el estudio de las medidas de control preventivas y curativas. Actualmente están en ejecución dos trabajos:

a. Evaluación y control de Sirex noctilio F (Hymenoptera: Siricidae) en plantaciones de Pinus spp.

b. Observaciones sobre la biología de Rhyacionia buoliana Schiff (Lepidoptera: Tortricidae).

Las LIMITANTES principales para ambas instituciones están directamente relacionadas con el menguado presupuesto asignado a la investigación. Esto trae como consecuencia escasos recursos humanos, principalmente de técnicos especializados en Entomología Forestal, así como también de personal de laboratorio y administrativo, además de laboratorios mal equipados y limitada disponibilidad de materiales y productos de laboratorio.

Por otro lado, la investigación en el área es incipiente y tiene una gran cantidad de propuestas con determinadas prioridades. Pero lamentablemente, la carencia de recursos hace que la mayor parte de los trabajos que se realizan están dirigidos a solucionar casos puntuales, para una plaga en un determinado lugar sin respetar dichas prioridades.

La falta de financiamiento para la investigación se debe al hecho de que la forestación en Uruguay encarada como una alternativa económica dentro de la actividad agropecuaria es relativamente reciente. Las plantaciones instaladas con fines maderables son jóvenes y están concentradas en ciertas zonas del país, por lo que en términos generales no se han registrado problemas graves de plagas. Sin embargo, existen en nuestros bosques insectos potencialmente peligrosos y se han dado algunos casos de aparición esporádica y/o no generalizada. A pesar de ello, dichos casos no despertaron en técnicos y productores conciencia del peligro que entrañan estos insectos.

Teniendo en cuenta las características antes expuestas en relación a la enseñanza, a la investigación y eventualmente a la extensión en Entomología Forestal en nuestro país, la PROPUESTA del grupo forestal en el Primer Encuentro Nacional sobre Entomología Agrícola realizado los días 16-17 y 18 de junio de 1988 fue la siguiente:

a. Docencia: jerarquizar la posibilidad de realizar cursos extracurriculares a dos niveles:

- a.1. Cursos de actualización para técnicos;
- a.2. Cursos de entrenamiento para personal de campo.

b. Investigación: prospección en el sentido amplio del término: detección, identificación y y evaluación biológica (niveles poblacionales y de daño) en viveros, plantaciones y productos forestales.

c. Extensión: la extensión comprendería standarización, recopilación y divulgación masiva de la información. El objetivo que se persigue con ello es que el productor conozca con que problemas de plagas se puede encontrar durante el ciclo productivo y en los casos en que sea posible, las medidas preventivas y de control.

Para llevar a cabo la investigación y la extensión sería necesario la cooperación entre distintas instituciones públicas y/o privadas.

De acuerdo a las normas vigentes existentes, se resalta la importancia de la fiscalización a través del cumplimiento de las normas de cuarentena. En tal sentido, se propuso además la confección de un mapa de distribución de plagas y la realización de una lista de posibles insectos plaga que puedan introducirse de las principales especies de interés forestal para su inclusión en las listas cuarentenarias uruguayas.

Por otra parte, se resaltó la importancia en el logro de una mayor cooperación a nivel regional (Argentina,Brasil,Chile, Paraguay y Uruguay) que tenga como finalidad el intercambio de información y la formulación y realización de proyectos regionales de investigación de insectos plaga comunes al área biológica de cada una de ellas.

Las propuestas emanadas del grupo forestal arriba mencionadas, sintetizan en grandes líneas las perspectivas de desarrollo de la Entomología Forestal en el Uruguay.

ESTADO ACTUAL DE LA ENTOMOLOGIA FORESTAL EN LA ARGENTINA

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FDC: 453: 41: 145.7: (82)

SUMMARY

A general view of the actual situation of the Forest Entomology is given. In this moment Argentina has about 35 million hectares of native forest and about 700.000 hectares of cultivated forest. The diagnostic of the situation indicates the lack of human resources (reduced number of forest entomologists) and educational problems (lack of training courses and Post-grade Studies). There is not general coordination of the research plans and few studies of pest behaviour and damage evaluation. There is not standarized information capable of determining the real importance of pests. It has not governamental financial support which in turn is derived to more traditional agricultural areas.

Key words: Argentina, forest pests, research priorities.

INTRODUCCION

La República Argentina cuenta con 35.180.000 ha de bosques nativos y 689.300 ha de implantados, los que se discriminan en: coníferas (principalmente pinos) 309.000 ha; eucaliptos 201.000 ha y salicàceas 130.000 ha (IFONA, 1985). Pese a la gran diferencia en superficie, los bosques implantados tienen mayor participación en las extracciones anuales que los nativos, estas totalizan unas 7.000.000 toneladas por año.

Por otra parte, las especies exóticas van adquiriendo cada vez mayor importancia debido al creciente ritmo de las exportaciones de este tipo de maderas, las que han pasado de 170.000.000 dolares en 1985 a màs de 250.000.000 en 1988.

En general, la entomología forestal està muy poco desarrollada en la Argentina. El número de entomólogos forestales es muy reducido; no se cuenta con una coordinación a nivel nacional, la información disponible es escasa, y no hay censos y estadísticas sobre la evaluación de los daños producidos por las plagas. Por ese motivo no se tiene conocimiento cierto acerca de la incidencia de ellas en el sector forestal.

DIAGNOSTICO

Para una mejor comprensión, podemos dividir en los siguientes aspectos el diagnóstico de la situación actual:

(a) Recursos humanos:

Se carece de entomólogos exclusivamente forestales.Se trata de técnicos de otras àreas que prestan apoyo al sector forestal, en general carecen de especialización a nivel de Post-grado en temas forestales.

Los profesionales dedicados a este tema pertenecen a algunas de las cuatro facultades forestales existentes en el pais, o bien a unas pocas universidades que tratan someramente el tema de entomología forestal y, en el menor de los casos a institutos de investigación agropecuaria (INTA,IFONA,CONICET,etc.).

(b) Enseñanza:

En la pràctica se imparten conocimientos de entomología forestal solamente en las cuatro facultades mencionadas. No existen en el pais cursos de capacitación ni enseñanza de post-grado.

(c) Investigación:

Se carece de coordinación general para el encauce de las investigaciones. Los estudios responden màs a la inquietud personal del investigador que a un plan preestablecido. La investigación entomológica forestal no cuenta con el debido apoyo financiero del gobierno ya que èste deriva los fondos hacia àreas agrícolas màs tradicionales. Los trabajos se restringen a la identificación de las plagas y, en ciertos casos, a su control inmediato. En la actualidad son poco frecuentes los estudios de bioecología de las plagas, su impacto en el medio ambiente y la evaluación de los daños producidos.

(d) Información disponible:

Debido a la situación precedente, se carece de información estandarizada, actualizada y que pondere la real importancia de las plagas. Normalmente, la información se restringe a observaciones de la presencia de la plaga a las que se añaden referencias bibliogràficas. Rara vez se cuenta con información sobre evaluación de los daños.

(e) Incidencia de las plagas:

Se carece de datos concretos para cuantificar los daños. Se acepta la importancia de algunas plagas aunque no éstas llegan a limitar la implantación de un bosque.

Entre los problemas que suelen presentarse, podemos citar como de importancia a nivel nacional a las hormigas, las que ocasionan problemas en viveros y especialmente en plantaciones jóvenes. Ya en la etapa de desarrollo de la masa boscosa, los problemas suelen ser màs específicos para cada región, como la mariposita del brote de pino en Córdoba, la mosca sierra en el Delta. Finalmente, la madera puede ser atacada según su estado de transformación, por una gama de taladros y polillas, variando su incidencia según la zona y especie.

METAS Y OBJETIVOS

Si bien no existe un plan nacional de desarrollo del sector entomológico forestal se considera importante alcanzar las siguientes metas:

(1) Creación de un servicio de protección forestal y la coordinación a nivel nacional de la investigación entomológica a fin de:
- Disponer de información estandarizada a nivel nacional.
- Estudiar debidamente las plagas en todos sus aspectos bioecológicos cuantificar los daños y determinar la incidencia de las plagas en el medio ecológico.
- Contar con pautas sobre los controles màs convenientes para cada plaga.

(2) Coordinar la investigación con otros países.
A fin de aunar esfuerzos y evitar superposiciones, se considera de gran importancia una comunicación fluida con otros países, tratando de concretar proyectos de cooperación.

(3) Capacitación de tècnicos en el exterior.
Para desarrollar una entomologia forestal sobre bases científicas y metodológicas modernas, se considera de suma importancia capacitar a tècnicos a nivel de post-grado para que puedan ser los pilares de la entomología forestal de nuestro país.

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PAIS : ARGENTINA

REGION DENTRO DEL PAIS: Todo el Pais

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PRINCIPALES INSECTOS, PROBLEMAS

I Forestación Natural

Extensión aprox. del
àrea si es conocida: 35.000.000 ha (todo el país)

Tipos principales de forestación: Subtropical húmedo y templado.

No	Especies de àrboles con flia. (1 - 5)	Plaga identificada con orden y flia	Naturaleza del daño	Extensión del àrea afectada si es conocida	Control practicado (si hay)	Si se està investigando al respecto SI/NO
1.	*Cedrela* sp. (Meliaceae)	*Hypsipyla grandella* Lep., Phycitidae	Barrenador de brotes Destruye plantas nuevas	Provincia de Misiones	Biológico y químico	SI
2.	*Prosopis* spp.(Leguminoseae	*Torneutus pallidipennis* *Megacylline* sp. Col.,Cerambycidae	Taladran tronco y ramas	Provincias de Formosa, Chaco y Región de Cuyo	NO	SI
3.	*Aspidosperma quebracho blanco* (Apocinaceae)	*Brasilianus lacordairei* Col., Cerambycidae	Taladran madera de àrboles cortados	Provincias de: Chaco Santiago del Estero y Formosa	NO	SI

4.	*Aspidosperma australis* (Apocinaceae)	*Brenthus anchorago* Col., Brentidae	Taladran madera de àrboles cortados	Provincia de Misiones	NO	SI
5.	*Schinopsis* spp. (Anacardiaceae)	*Crysobothris holochalcea* Col., Buprestidae	Taladran madera de àrboles cortados	Provincias de Chaco, Formosa, Salta y Santiago del Estero	NO	SI

II *Plantaciones*

Area aprox. si es conocida:
1. Especies Nativas (27.000 ha)
2. Especies Exóticas (700.000 ha)

No	Especies de àrboles con flia. (1 - 5)	Plaga identificada con orden y flia	Naturaleza del daño	Extensión del àrea afectada si es conocida	Control practicado (si hay)	Si se està investigando al respecto SI/NO
			Especies Nativas			
1.	*Araucaria angustifolia* (Araucariaceae	*Atta* spp. *Acromyrmex* spp. (Hym., Formicidae)	Se alimentan de follaje de plantas jóvenes	Provincia de Misiones	Cebos tóxicos (Mirex) Clorados	SI
		Laspeyresia araucariae (Lep., Grapholithidae)	Las larvas se alimentan de semillas		Quimico	SI
			Especies Exóticas			
1.	*Pinus* spp. (Pinaceae)	*Atta* spp. *Acromyrmex* spp. (Hym., Formicidae)	Se alimentan de acículas de plantas jóvenes	Todo el país	Cebos tóxicos (Mirex) Clorados	SI

	Ryacionia bouliana (Lep.Grapholithidae	Destruye brotes	Provincias de Córdoba y San Luis	Biológico	SI
2. *Eucalyptus* spp. (Myrtaceae)	*Atta* spp. *Acromyrmex* spp. (Hym., Formicidae)	Se alimentan de follaje de plantas jóvenes	Mesopotamia,Bs.As. Córdoba y Sta.Fé	Cebos tóxicos (Mirex) Clorados	SI
	Diloboderus abderus Col., Scarabidae	Se alimentan a nivel del cuello de plantas jóvenes	Provincia Entre Rios	NO	NO
	Phoracantha Semipumctta Col., Cerambycidae	Taladra àrboles debilitados y apeados con corteza	Mesopotamia	NO	NO
3. *Salix* spp. y *Populus* spp. (Salicaceae)	*Nematus desantisi* Hym., Tenthredinae	Defoliación	Provincias Bs.As.Mendoza Región del Delta 120.000 ha aprox.	Químico (Piretroides)	NO
	Acromyrmex spp. *Atta* spp. Hym.,Formicidae	Defoliación		Cebos tóxicos (Mirex) clorados	NO
	Platypus sulcatus Col.,Platypodidae	Perforan el tallo		NO	NO
	Oiketicus platensis Lep.,Psychidae	Defoliación		Productos biológicos y Fosforados	NO
4. *Melia azedarach* (Meliceae)	*Hypsipyla grandella* Lep.,Phycitidae	Perfora produce deformaciones	Provincia Misiones	Biológico y Químico	SI

III. Madera cortada

No	Material (1-5)	Plaga	Naturaleza del daño	Control practicado si hay	Si se esta investigando al respecto SI/NO
1.	Troncos y rrollizos verdes (nativos y exóticos)	*Platypus* spp.Col., Platypodidae *Xyleborus argentinensis* Col.,Scolytidae	Taladran la madera	NO	SI
2.	Madera estacionada y seca(indígenas y exóticas	*Lyctus* sp. *Trogoxylon* sp. Col.,Lyctidae *Xyletinus* sp. *Anobium* sp. Col.,Anobiidae	Perforan madera	Químico preventivo	SI
3.	Madera de *Schinopsis* spp.	*Hamaticherus lacordairei* Col.,Cerambycidae	Taladra madera	NO	NO

NOTA: Se agradece la información brindada por los Ings.Agrs. Jorge Vizacarra Sànchez (Prof.Entomología Ftal - F.C.F. de Misiones, Gustavo Rodriguez (INTA - Misiones) y Rafael Sirven (IFONA - Castelar).

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THE ROLE OF EUCALYPT PLANTATIONS IN TIMBER SUPPLY AND FOREST CONSERVATION IN AUSTRALIA

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FDC: 238: 176.1 Eucalyptus spp.: 721.1: 907: 62: (94)

SUMMARY

Supplies of timber in Australia will incease rapidly over the next 20 years as trees in existing softwood plantations reach harvestable size. Demand for sawlogs is expected to be almost satisfied from domestic supply by the year 2010, despite reduced supplies from native forests. Supply of pulplogs is expected to substantially exceed demand over the next 40 years but existing capacity to produce pulp and paper in Australia is well below domestic consumption.

Softwood plantations that were established despite major opposition from conservation organisations, now play a major role in wood supply and have reduced our dependence on native forests. There is strong pressure from conservation organisations to cease logging in old-growth forests and a conservation oriented forest strategy has been proposed that includes increased establishment of eucalypt plantations for sawlogs and pulpwood.

Relatively small areas of eucalypt plantation have been established to date but the rate of new planting has recently increased. Results of recent research demonstrate that growth rates of eucalypts in Australia can match the best achieved overseas. Investment in plantations to produce pulpwood on short rotations would provide a good return but growing sawlogs on longer rotations would be less profitable and optimum management regimes have not been defined. However, application of more intensive management regimes in existing regrowth forests can reduce expected rotation lengths, improve productivity and produce both sawlogs and pulpwood.

A conservation oriented timber strategy that relies on production of sawlogs from plantations and is not seen as feasible at this point in time. A strategy based on pulpwood plantations at strategic locations near pulpmill sites is proposed, combined with more intensive management of regrowth forests to provide both sawlogs and pulpwood for industrial development. A substantial increase in research and development is required to improve productivity and wood quality of trees grown in plantations. In locations where insufficient private land is available for plantations to support a mill, areas of native forest should be leased to industry for plantation development. These plantations would provide experimental sites for research to define optimum management regimes required to produce sawlogs from plantation-grown trees so that areas of high conservation value can be removed from timber production in the future.

INTRODUCTION

For the first hundred years of settlement in Australia, forests of the colony suffered gradually increasing attacks from two fronts: The forest was seen firstly as an inexaustible source of wood for local or export needs and secondly as an impediment to cultivation of the soil and grazing of livestock for production of food (Carron 1985). By 1870 there was concern in NSW that lack of control over tree cutting on crown land and indiscriminate removal of forest on leasehold and freehold land would soon leave no land for permanent production of wood. The history of land clearing and overcutting of forests in NSW was repeated along similar lines in other States. During the early 1900s, forest reserves were gradually gazetted, forestry activities brought under the control of professional foresters in State forestry services and proper legislative backing introduced (Carron 1985).

State forestry services were thus created with a charter to control cutting of trees, ensure continuing supplies of timber and produce income from reserves set aside for the purpose. They soon became involved in establishing plantations, particularly of softwoods, to replace substantial imports of coniferous timber from North America and Europe. The fact that conservation organisations have recently nominated many timber reserves for world heritage listing or national parks indicates that the forest services have been eminently successful in fulfilling their charters of conserving and managing the forest resource on reserves under their control. However, sustainable rates of growth in many native forests are low and production has been insufficient to meet domestic consumption.

Public attitudes to forestry have changed radically over the last century and there is mounting pressure on Governments to cease timber cutting in many native forests that were originally reserved for that purpose, particularly in old-growth forests that have not yet been cut for timber (Cameron and Penna 1988). These demands are being made in spite of the high level of imports of forest products into Australia. For instance, $1.7 billion worth of wood products were imported in 1986-87, accounting for nearly 10 per cent of Australia's total trade deficit (Hossain *et al.* 1989). High-value pulp and paper products accounted for 60 per cent of this amount and by comparison, low value woodchips worth some $300 M were exported.

Both industry (FAFPIC 1987) and conservation organisations (Cameron and Penna 1988) agree that Australia should reduce dependence on imported forest products and thus reduce our trade deficit. Establishment of additional plantations has been proposed by both authors to help alleviate this imbalance. Clarke and Blakers (1989) reject the need for additional Government involvement in hardwood plantation establishment and place emphasis on recycling of paper. Rates of paper recycling in Australia have been very good in the packaging industry for many years but almost non-existent for newspapers. Introduction of new technology for de-inking paper may improve this situation in the near future but there is a limit to the number of times paper fibres can be re-used. More intensive management of regrowth forests has also been suggested to increase productivity in native forests (Rawlins *et al.* 1985).

Given the current level of controversy over logging of native forests in Australia, it is incumbent on the forestry profession to provide a timber strategy that enables domestic wood production and processing to be increased in specific locations, while protecting other areas determined to be of high conservation value. This paper addresses some of the relevant issues in this debate and outlines a strategy that may provide common ground for further discussion.

AVAILABILITY AND CONSUMPTION OF WOOD

Predicted trends in consumption of sawntimber, wood based panels and paper and pulp products to the year 2030 made by Cameron and Penna (1988) and Hossain *et al.* (1989), were in fairly close agreement and reflect a reasonable growth in domestic markets. Predictions proposed by FAFPIC (1987) appear to assume a considerable expansion in exports and a growth in per capita consumption in Australia.

Availability of softwood sawlogs will increase rapidly over the next 20 to 30 years as trees in existing coniferous plantations reach merchantable size. Domestic supply of sawn timber is thus likely to almost balance domestic consumption by 2010, despite a decline in availability of hardwood sawlogs. By comparison, availability of pulplogs is expected to substantially exceed supply from now until at least 2030 (Hossain *et al.* 1989). Ability to utilise pulplogs (often thinnings or residues) depends on distance to mill and many areas could not be harvested economically. However, there is agreement that woodchips that are currently exported should be converted to pulp and paper products in Australia.

World hardwood pulp production has doubled since 1974 and has been driven by new bleached kraft mills using plantation-grown eucalypts, predominantly in South America, South Africa and Portugal (Woodbridge, Reed and Associates 1986). An expanding world market exists for kraft bleached hardwood pulp whereas the market for unbleached pulp is shrinking (Fandry *et al.* 1989). The scale of new bleached kraft pulp mills currently exceeds 400,000 t a^{-1} but as one such mill exceeds the total demand for such pulps in Australia, viability is dependent on the ability to compete on world markets. It is important to recognise that the domestic paper industry must also compete successfully with international competitors on domestic markets.

Domestic production of pulp and paper in large-scale modern mills in Australia could replace imports and would have good prospects for export but lack of sufficient volume of wood in suitable locations is seen as a major obstacle to such proposals (Jaakko Poyry 1986). Eucalypt plantation projects already underway in northern Tasmania and Western Australia will eventually provide a substantial proportion of the wood required for mills proposed in those areas. By comparison, no major plantation projects are in place in east Gippsland and/or south east NSW near potential pulp mill sites.

FOREST AREAS

Native forests

Australia has a land area of slightly under 770 M ha but most of the centre is semi-arid or desert. Much of the land that receives more than 500 mm of rain and formerly supported woodland or forest at the time of european settlement in 1788 has been cleared for agriculture, urban development and other purposes. Recent resource data quoted below apply to the end of June 1987 unless otherwise stated (ABARE 1988; AFC 1989).

Closed-canopy forest, consisting of trees that potentially exceed 20 m in height at maturity, covers only 35 M ha, equal to 4.5 per cent of the land area of Australia. Some 80 per cent of these forests are dominated by eucalypts, the remaider includes 4.3 M ha of cypress pine (*Callitris* spp.) and 2.0 M ha of rainforest (both tropical and temperate). These data exclude tropical paperbark/eucalypt forests covering some 6.5 M ha in northern Australia that are not currently used for production of timber.

Of the 35 M ha of forest land, 8.8 M ha (25%) is privately owned and although only a small proportion of this is managed for wood production, private forest has supplied up to 30 per cent of the timber from native forests for many years. Of the public land, 4.6 M ha have been reserved as National or State Parks and have thus been removed from timber production (this represents 13% of all forest land and 18% of public forest land).

Vacant forested crown land or forested land occupied under crown lease covers 8.6 M ha (24%) and is not reserved for timber production but some timber harvesting is carried out under Government control. State forests cover 12.3 M ha (35%) and while reserved primarily for timber production, are managed for multiple use. Thus timber harvesting has been expressly excluded from 0.8 M ha that has been specifically reserved for conservation purposes. In addition, routine logging has been modified or restricted due to management priority, for other values or due to economic reasons on a further 4.5 M ha. This leaves only 7.0 M ha (20%) of native forest land expressly set aside for timber production within a multiple use framework. There are less than 1.0 M ha (3%) of plantation, most of which is coniferous.

Regrowth forests

Substantial areas of high-quality forest have been logged in Victoria and Tasmania since 1950 (species include the 'ashes' *E. regnans* and *E. delegatensis*, plus *E. nitens* in Victoria and *E. obliqua* and *E. globulus* in Tasmania). It has been estimated that almost 96,000 ha (58,500 in Victoria and 37,300 in Tasmania) of even-aged regrowth resulting from those logging operations is both available and accessible for intensive management (Wells 1990). Additional areas of regrowth exist that have not been assessed for availability, including some 137,000 ha of high quality ash regrowth in Victoria and Tasmania that resulted from fires between 1934 and 1949; a further 53,000 ha of lower quality regrowth forest in Victoria and Tasmania; 32,000 ha of even-aged regrowth of *E. diversicolor* in the south west of Western Australia; and significant but unquantified areas of ash regrowth in NSW (Wells 1990).

Plantations

Plantation development in Australia has concentrated on coniferous species, due to the apparent abundance of native hardwoods and the dearth of native softwoods. The total area of coniferous plantation as at March 1987 was about 858,000 ha, of which 70 per cent was owned by State forest services and the remainder was private (AFC 1989). Published data indicate that there were 42,000 ha of eucalypt plantations in March 1987 but these and other recent data exclude approximately 20,000 ha planted or purchased by the NSW Forestry Commission. Actual planted area in 1987 thus would have exceeded 60,000 ha, of which two-thirds were publicly owned.

Interest in hardwood plantations has intensified recently and both conservation (Cameron and Penna 1988) and industry organisations (FAFPIC 1989) have proposed increased rates of planting. Rates of new planting estimated by both authors were in general agreement (Table 1)

Table 1. Expected rate of eucalypt plantation establishment in 1989 (from Cameron and Penna 1988; FAFPIC 1989).

State	Organisation	Rate (ha a^{-1})
Victoria:	CF&L Department	2,000
	APM Forests	1,000
W.A.	CALM Department	1,000 - 2,000
	WACAP	600 - 1,000
	Macleans	400 - 1,000
Tasmania	APPM	2,500
	Forest Resources	500 - 1,000
	Total	8,000 - 10,500

Data in Table 1 may be under-estimates as Wells (1990) reports that in excess of 5000 ha were planted in Tasmania alone in 1989. The total area of eucalypt plantation is therefore likely to double to at least 120,000 ha by 1995 if the expected annual rate of new planting does in fact occur and continues for 6 years. This would result in an area of eucalypt plantation greater than that proposed by FAFPIC (1989).

PRODUCTIVITY

Native forests

Total estimated removals of hardwood logs in 1986-87 was 11 M m^3 from 7 M ha of public forest land and 8.8 M ha of private land (Hossain *et al.* 1989). Some 70% of the removals (7.8 M m^3) came from the 7.0 M ha of public land managed for timber production, so that 'average' productivity of these forests was only marginally above 1 m^3 ha^{-1} a^{-1}. High quality 'ash' type forest in Victoria, regenerated from seed and managed on an 80-year rotation for sawlogs without thinning, has been estimated to have a MAI of about 12 m^3 ha^{-1} a^{-1} (Rawlins 1990). By comparison, average annual growth rate of conifer plantations was estimated to be in the order of 18 m^3 ha^{-1} a^{-1} (AFC 1989). The mean productivity of pine plantations per unit area of land thus exceeds that of 'average' native forests by a factor of almost 20, and is about 50 per cent higher than high-quality ash regrowth.

More intensive management of existing regrowth forests can increase productivity. For instance, early thinning of regrowth forests can reduce the land area required by 50 per cent and rotation length by 30 years (Rawlins 1990). Increased production from more intensive management of regrowth will provide more immediate benefits, including better quality saw timber than introduction of more intensive establishment methods in plantations. Application of fertiliser to existing plantations and regrowth forests at time of thinning could both provide fairly immediate benefits but little research has been done in this area.

Plantations

Productivity of eucalypt plantations is more difficult to determine as most plantation projects started less than 30 years ago and the intensive techniques used for conifer plantations have only recently been applied to eucalypt plantations in Australia. Growth data for plantations of a range of eucalypt species established prior to 1970 were presented by Borough *et al.* (1978); Mean annual increment (MAI) of the better plantations of *E. grandis*, *E globulus*, *E. nitens* and *E. regnans* ranged from 15 to 30 m^3 ha^{-1} a^{-1} depending on species, site quality and rotation length. Most of these plantations would have been established without ground preparation, with minimal weed control and may or may not have had a small starter dose of fertilizer. Seedlings would have been raised from seed of natural stands with no genetic improvement and there would have been little or no information on the best species or provenance to plant.

RESEARCH AND DEVELOPMENT

Pulpwood

In the years since the above data were published (Borough *et al.* 1978), the area planted to eucalypts has approximately doubled and there has been some additional research directed towards increasing productivity. Forestry research is a very long term investment, as not only does the research itself take many years to complete, but full incorporation of results into management prescriptions may take up to one full rotation.

For example, APM Forests Pty. Ltd. (APMF) and the Forest Research Institute (now CSIRO Division of Forestry and Forest Products), began research on *Pinus radiata* in Gippsland, Victoria, in the late 1950s. Results of this research, in the form of improved seed, better ground preparation, chemical weed control and heavier rates of fertilizer, began to be incorporated into operational prescriptions during the early 1970s. Management inventory plots established by APMF in plantions at 10 years of age have shown that MAI increased by 50 per cent from an average of 10.2 m^3 ha^{-1} a^{-1} in plantations established before 1973, to 15.4 m^3 ha^{-1} a^{-1} in 1977 plantations (Cameron and Leishout 1988). MAI of plots measured at 10 years of age has been about half of that achieved over a rotation of 27 years, suggesting that over a full rotation, growth could increase from about 20 m^3 ha^{-1} a^{-1} in pre 1973 plantations to about 30 m^3 ha^{-1} a^{-1} after 1977. It is important to recognise that it will take a full rotation of 27 years for these improved establishment practices and genotypes to be incorporated across the whole plantation estate and a further 27 years to obtain the entire benefit when the last compartment is felled.

There is increasing evidence that species of the Sub-genus Eucalyptus (Monocalyptus or ashes) grow less rapidly on short rotations than species of the Sub-genus Symphyomyrtus (including *E. grandis*, *E. globulus* and *E. nitens*). Recent experiments have demonstrated that more intensive cultural practices, particularly when applied to these latter species, can lead to dramatic increases in productivity. Rates of growth now being measured in the best treatments in experiments in Australia are more in line with the highest rates reported overseas, as shown below:

i) A major plantation experiment was established in the Esperence Valley in south-eastern Tasmania in 1983, on four sites that ranged in elevation from 60 to 650 m. Sites were ploughed, weeds were chemically controlled and fertilizers containing 410 kg of nitrogen and 180 kg of phosphorus ha^{-1} were applied over the first 3.5 years. Growth of all species decreased with increasing elevation, and *E. nitens* grew faster than three other species including *E. globulus*, *E. regnans* and *E. delegatensis*. At five years of age, MAI of the best provenance of *E. nitens* ranged from 13.6 m^3 ha^{-1} a^{-1} at 650 m, to 23.4 m^3 ha^{-1} a^{-1} at 60 m. Current annual increment (CAI) at 60 m exceeded 45 m^3 ha^{-1} a^{-1} at age five years so that MAI was still rising rapidly (Turnbull *et al.* 1989). The dramatic difference in early patterns of growth between species was found to be entirely due to the generation and maintenance of a high leaf area index (leaf area per unit ground area) and therefore high light interception (Turnbull *et al.* 1988).

ii) In a review of eucalypt trials in Tasmania, Tibbits (1986) observed that *E. nitens* and *E. globulus* ssp. *globulus* had shown significantly superior early growth compared with 24 other species examined. He reported that *E. globulus* had achieved MAI's of about 30 m^3 ha^{-1} a^{-1} between 11 and 23 years of age in trials near Burnie and that the best family of *E. nitens* had achieved a similar MAI by age 9. An experiment planted with *E. nitens* in the Strzelecki Ranges, Victoria also produced a MAI of 30 m^3 ha^{-1} a^{-1} at 10 years of age (Whiteman 1988).

iii) Treatments applied to an experiment with *E. grandis* near Coffs Harbour NSW included ploughing, weed control, insect control and heavy fertilization. Stemwood biomass at 9.25 years of age averaged 86 t ha^{-1} in control plots (ploughed only) and 202 t ha^{-1} in plots which had received maximum treatment (E. Birk and J. Turner, pers. comm. Dec. 1989). Average wood density in trees from control and fully-treated plots was 441 and 472 kg m^{-3} respectively (Wilkins and Horne 1990). MAI would thus have ranged from 20 to over 40 m^3 ha^{-1} a^{-1} with increasing intensity of treatment.

iv) An experiment planted with *E. grandis* in 1987 near Gympie, Queensland, that included heavy applications of fertilizer in combination with ground preparation, weed and insect control, produced trees with a mean height of 13.6 m at two years of age (Cromer *et al.* 1989). Such rapid height growth has not been recorded previously in Australia and is similar to that reported for outstanding clones at Aracruz in Brazil, with MAI's claimed to be greater than 50 m^3 ha^{-1} a^{-1} (Campinos 1980).

Some of these examples refer to total rather than merchantable volume and most represent growth of the best species and treatments in research experiments. Although operational plantations would not be expected to reach such high rates of growth (Drielsma and Wilson 1989), they demonstrate that very high rates are possible in eucalypt plantations in Australia and investment in research will push those boundaries further.

Sawlogs

Sawmills in Australia have historically sawn large logs with diameters (at 1.3 m) often of one metre or more, harvested from old-growth forests. Growth stresses in eucalypt logs cause spring and bow as they are sawn but this problem is minimised in large logs. The diameter of logs supplied to mills in Australia will decrease of necessity as old-growth forests are cut over and mills convert to regrowth forests. A rotation of 80 years without thinning has been regarded as the standard "extensive" management regime required for ash regrowth to produce sawlogs. However, recent research using growth modelling techniques has demonstrated that early thinning to promote diameter growth increases MAI and reduces rotation length. In the best case (non-commercial thinning at age 5, followed by a pulpwood thinning at age 20), MAI increased from 12 to 18 m^3 ha^{-1} a^{-1} and rotation length decreased from 80 to 50 years (Rawlins 1990).

Given appropriate thinning regimes, plantations could be grown for pulpwood and sawlogs or specifically for sawlogs, with some pulpwood as a by product. A comprehensive set of spacing trials were planted with *E. grandis* at two sites in southern Africa in 1952 (Langepan 32° 10' E, 28° 40' S, and Nyalazi 32° 23' E, 28° 12' S). Trees were planted at high density initially and thinned heavily in the low density plots over several years, resulting in densities that ranged from 6726 to 30 stems ha^{-1}. Langepan was a good site (mean annual rainfall 1388 mm) and trees in plots that had been thinned early to 124 stems ha^{-1} had a mean diameter at breast height (DBH) of about 55 cm at 22 years of age (van Laar and Bredenkamp 1979). Even at the drier site of Nyalazi (993 mm), trees thinned to these low densities had a mean DBH of about 50 cm after 22 years (Bredenkamp 1987). At densities of less than 124 stems ha^{-1}, diameter growth was even greater but productivity fell dramatically.

An agroforestry experiment near Brisbane, Queensland, included planting densities from 42 to 3,580 stems ha^{-1} (Cameron *et al.* 1989). At 4.6 years of age, trees planted at densities of between 82 and 300 stems ha^{-1} had reached a DBH of 16 cm or greater. Such low densities or extremely heavy thinning regimes designed to produce large diameter logs on relatively short rotations, naturally have substantially lower total production than plantations grown at more conservative tree densities. Perhaps more importantly, trees grown at low densities produce large branches that reduce the value of sawn timber and branch stubs that create potential sites for fungal infection which degrades wood quality.

There is some evidence that growth stress in eucalypts is inversly related to tree size (rather than age), so trees grown rapidly in response to heavy early thinning or fertilizer applications should be acceptable for sawing, provided they are a sufficiently large in diameter. Trees of *E. grandis* that grew rapidly as a result of intensive treatment (see R & D section iii above), had higher wood density (Wilkins and Horne 1990), more intense colour (Wilkins and Stamp 1990), and lower growth stresses (A.P. Wilkins pers. comm. 1989) than trees that grew more slowly in control plots.

It is clear that industry is not in a position to establish eucalypt plantations specifically for sawlogs on short rotations at this point in time. Recent research results quoted above are very promising but a substantial R & D effort is required to determine optimum spacing and thinning regimes to minimise branch size and maximise diameter growth in species most likely to be used for this purpose. Effort is also required to utilize significant inter- and intra-specific genetic variation in important wood properties. The best option for rapidly increasing the volume of hardwood sawlogs in the near future is to thin existing regrowth forests, producing an intermediate yield of pulpwood, and reducing the rotation length required to produce sawlogs.

LAND REQUIREMENTS

The land area required to support a wood processing industry reduces as intensity of forest management increases. The example in Table 2 demonstrates that establishment of intensively-managed plantations can potentially reduce the land area required to support a pulp mill by a factor of 30. Average transport distance can potentially be reduced by a factor of 5 but such a benefit is unlikely to be realised in practice.

Table 2. Land area and average haul distance for forests of different productivities to supply a mill with 1.5 M m^3 of wood per annum.

Forest type	Growth rate (m^3 ha^{-1} a^{-1})	Land area for production (ha)	Av. haulage * distance (km)
Native forest (average)	1	1 500 000	98
Native forest (good)	5	300 000	44
Plantation or regrowth (A)	15	100 000	25
Plantation (B)	30	50 000	18

A: i) Plantation on a poor site or prior to use of latest technology,
ii) Regrowth 'ash' forest under intensive management.
B: A good site and/or when research results effectively implemented.
* A circular area with a mill located at the centre was assumed.

It has been proposed that all new plantations be established on private land, through purchase, sharefarming, leasing or other arrangements (Cameron and Penna 1988). However, in some locations, the amount of private land available for plantations is unlikely to be sufficient to support a major pulpwood industry, and competition for land would disrupt farming communities and increase land prices (FAFPIC 1989).

To provide an incentive for industry to invest in pulpmills, small areas of existing native forest could be allocated specifically for plantation establishment close to proposed mill sites. An area of leasehold land, say of about 50,000 ha in east Gippsland, in the Eden area or near other proposed mill sites would provide sufficient land to ensure primary wood supplies for a mill and compensate for areas removed from production for conservation purposes. License agreements could require industry to initiate sharefarming agreements with local landholders for additional wood. Such an initiative is in line with the interim strategy proposed by the Australian Conservation Foundation (Cameron and Penna 1988) "to indentify forest areas .... of sufficient size to provide pulplogs for 15 years and sawlogs for 15-30 years".

ECONOMIC CONSIDERATIONS

A comparison of the economic returns from *E. regnans* in Tasmania grown under three management regimes (regeneration by seed, extensive plantation and intensive plantation), showed that net present value (NPV) from investment in intensively managed plantation was more than double that from regeneration (Turnbull *et al.* 1989). No account was taken of potential reductions in transport costs or a change of species from *E. regnans* to the faster-growing *E. nitens* that presumably would have shown even higher returns for the intensive plantation regime.

A preliminary economic analysis by Rawlins *et al.* (1985) compared the break-even pulpwood price of extensively and intensivelty managed regrowth with short rotation plantations. The delivered cost of wood from regrowth thinned at 7 years of age was substantially lower than regrowth thinned later or not thinned at all and compared favourably with the cost of wood from short rotation plantations.

Few comparative data are available on the economics of intensive silviculture in eucalypt plantations but the above results are in line with substantially reduced growing costs reported for *Pinus radiata* following higher application rates of fertilizer and better weed control (Cromer *et al.* 1977; Dargavel and Cromer 1979).

Economic returns from investment in thinning regrowth forests are also attractive. NPV of the most intensive thinning regime examined in 'ash' regrowth in Victoria (thin to waste at age 5, merchantable thin at age 20 and clearfall at age 50) was more than three times the NPV of the standerd regime of no thinning and clearfall at age 80 (Rawlins 1990).

Cameron and Penna (1988) proposed that eucalypt plantations should be sawlog driven, but their own economic evaluations demonstrated that short rotation pulpwood regimes were far more profitable. There is ample evidence that application of existing technology would enable eucalypt pulpwood to be grown in plantations that would be commercially viable. Creation of such plantation estates primarily for pulpwood would enhance opportunities for ongoing research and development into sawlog production from plantations.

CONCLUSIONS

The conservation-oriented Forest Industry Strategy proposed by Cameron and Penna (1988), has considerable merit and benefits such as increased labour productivity, higher skill levels and employment stability leading to higher wages and safer working conditions are realistic. The technology exists in Australia now to obtain reasonable rates of growth in eucalypt plantations grown for pulpwood and provide a profitable return on investment. However, a large investment in research and development is required to underpin such plantation developments and increase growth rates to levels more in line with those observed overseas. Long lead times may be required to fully incorporate research results into management prescriptions and without a strong committment to reseach, productivity of proposed pulpwood plantations will fall below anticipated levels.

It will undoubtedly be possible to grow eucalypt sawlogs in plantations in the future but industry could not rely on such a strategy at the present time. Promising results from research experiments need to be followed up to ensure that timber quality from plantation-grown trees is adequate for the needs of industry. Such research is very long term in nature and has little support or funding from industry, conservation or government sources at present.

An alternative timber strategy is proposed as follows:

1) Government incentives be put in place to encourage industry and private landholders to establish eucalypt plantations for pulpwood near locations designated as future pulpmill sites.

ii) Where sufficient private land is not available to support a mill, reserved state forest land should be leased to industry for plantation establishment. Industry should be required to seek agreements with private landholders to grow additional plantations on their land.

iii) Initiate more intensive management of regrowth forests to provide pulpwood and sawlogs while plantations are developed.

iv) Establish a Research and Development Corporation, with contributions from the timber industry, forest growers, conservation organisations and governments. The Corporation would fund research and development to increase productivity of eucalypt plantations and regrowth forests and the production of sawn timber from young eucalypts.

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ROLE OF EUCALYPT PLANTATIONS IN TIMBER SUPPLY AND FOREST CONSERVATION IN SUB-SAHARAN AFRICA

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FDC: 238: 176.1 Eucalyptus spp.: 721.1: 907: 62: (213)

SUMMARY

The role of eucalypt plantations in timber supply and forest conservation in Sub-Saharan Africa was investigated. The annual destruction of 11,5 million ha of tropical forest is highlighted, the various causes indicated and the controversy whether fast-growing plantations and woodlots have a role to play in the conservation of these forests is discussed. It is shown that the total eucalypt estate in Sub-Saharan Africa exceeds one million ha of which 75% are for commercial purposes, which represents 16% of the world's total area. It is estimated that up to 30 000 ha of new industrial plantations will be established per year for the next five years while the annual extension of fuelwood plantations and woodlots should amount to at least double that area. Growth rates of eucalypts vary widely from 1,2 to 70 m^3/ha/year, depending on site conditions and silvicultural techniques. Under average conditions rates between 15 and 25 m^3/ha are achieved. It is expected that correct site/species matching, improved stock and adequate silviculture can improve these growth rates by at least 40%. The growth rates of natural forests and open woodland are low. To protect these resources it is estimated that in Sub-Saharan Africa at least 25 million ha of plantations and woodlots with fast-growing species are required to satisfy the demand for fuelwood and other rural needs. The role of eucalypts in supplying large-sized timber is relatively small. The impact of research on eucalypt growing is highlighted for two countries. In the Congo the development of clonal forestry has been a great success, while it is estimated that developments in the fields of genetics, site research and silviculture can increase the yields in South Africa by at least 40%. It is indicated that the future expansion of eucalypt plantations can be substantial due to the increased demand for hardwood pulpwood. Eucalypts can also play a considerable role in the supply of fuelwood but other species may be more preferred.

Keywords: Forest destruction, plantation areas, growth rates, research impact

INTRODUCTION

Worldwide concern exists about the destruction and degradation of natural forests in the tropics and subtropics. This is particularly the case for the equatorial rain forests which are deforested by approximately 7,5 million ha annually, and the open and savanna woodlands of which the annual destruction is about 4 million ha (Schmidt, 1987). The causes of deforestation are well known. They include population pressure for agricultural land, the demand for fuelwood and fodder, the unsustainable exploitation of forests for industrial timber production and export, and inappropriate policies regarding land tenure, economic incentives, forest settlement and other population issues (Anon, 1987[a]). These are especially serious in Africa where 63% of the energy consumption is derived from fuelwood (Mansour Khalid, 1986) and where countries such as Nigeria and the Ivory Coast, once rich in equatorial rain forests, have become net importers of timber and forest products (Burley *et al*, 1989). Various assessments of the progress of deforestation in Africa have been made, which indicate that from the 717 million ha in 1980 only between 657 million (best) and 300 million ha (worst) will remain in the year 2025 (Palo and Mery, 1986).

It is a controversial issue whether this process can better be counteracted by improved management of the remaining forests or by reforestation with fast-growing species in industrial plantations and woodlots. It is a well-known fact that mature or stable tropical forests in equilibrium have by definition no increment, the annual increment of timber being lost through natural wastage (Anon, 1987[b]). On the other hand, plantations with fast-growing species in the tropics and subtropics can produce under commercial conditions about 40 m^3 of timber per ha per year and even more under favourable conditions. Some foresters argue that plantation-grown timber is more expensive than that from the natural forest (Schmidt, 1987) and others suggest that plantation forestry will accelerate natural forest destruction (Anon, 1987[b]). However, these ideas are based on subjective cost accounting and the misconception that natural forests have to give way for man-made plantations. Admittedly, the latter has taken and is taking place, but most plantations are established on already deforested land or natural grasslands. It is regrettable, therefore, that IUFRO Division 2 could not accept at the 18th World Congress the declaration of the Symposium on Site and Productivity of Fast-Growing Plantations in 1984 which stressed the increased reliance which has to be placed on fast-growing industrial plantations, fuel plantations and woodlots. Furthermore, it was recommended that IUFRO should recognise the role which fast-growing plantations can play in future timber demands and promote their research and establishment in ecologically suitable areas (Anon, 1984).

This paper briefly reviews the role of eucalypt plantations in timber supply and forest conservation in Sub-Saharan Africa, i.e. Africa excluding the mediterranean countries such as Morocco, Algeria, Tunisia, Libya and Egypt. Special reference will be made to the existing plantation area, rate of new plantings, productivity of plantations, conservation of natural forests, impact of research and the expected future scenario.

EXISTING EUCALYPT PLANTATIONS

A complete picture of the extent of eucalypt plantations cannot be given since statistics for only 30 of the more than 40 states in Sub-Saharan Africa could be obtained in the limited time available. In addition, for some countries no exact eucalypt plantation areas are available or the eucalypt component of total man-made plantations are unknown. This is the case for (main species or total area in brackets) Benin (*E.camaldulensis*), Burundi (70 000 ha), Kenya (150 000 ha), Mauritius (11 500 ha), Mozambique (35 600 ha of which *E.grandis*, *E.camaldulensis* and *E.tereticornis*), Niger (irrigated *E.camaldulensis*) and Tanzania (< 10 000 ha eucalypts). Furthermore some countries are too arid or possess no plantations, e.g. Djibouti, Somalia and the Seychelles, while other countries have concentrated on other species such as *Gmelina arborea*, *viz* Liberia and Nigeria, or *Terminalia* spp, e.g. the Ivory Coast, Nigeria and Zaire.

For 17 countries more reliable data are available. These are summarized in Table 1, separately for industrial plantations supplying sawlogs, pulpwood, mining timber etc, and for various sized woodlots for protection or the supply of fuelwood, poles, building material or fodder to local communities. It must be noted that the reference years vary considerably.

TABLE 1 : Distribution of most important eucalypt plantations in Sub-Saharan Africa

Country	Eucalypt plantations (ha)			Main species	Year	Reference
	Industrial	Woodlots	Total			
Angola	50 000	-	50 000	*E.grandis*	1985	Jaakko Pöyry, 1987
Botswana	396	50	446	*E.camaldulensis*	1986	Burley *et al*, 1989, Anon, 1988, Van der Zell, 1989
Burkina Faso	3400	3 000	6 400	*E.camaldulensis*	1988	Zech *et al*, 1989
Comores	-	200	200	?	1986	Burley, *et al*, 1989
Congo	33407	-	33 407	*E.urophylla x grandis*, *E.alba x camaldulensis*	1988	Delwaulle, 1988 Vigneron, 1989
Ethiopia	-	90 000	90 000	?	1985	Burley, *et al*, 1989
Lesotho	-	5 767	5 767	*E.rubida*	1986	Burley, *et al*, 1989
Madagascar	130 000	-	130 000	*E.robusta*	1980	Burley, *et al*, 1989
Malawi	9 455	7 290	16 745	*E.grandis*	1985	Burley, *et al*, 1989
Nigeria	5 000	5 900	10 900	Many species	1985	Burley, *et al*, 1989
Rwanda	-	60 000	60 000	*E.camaldulensis*, *E.grandis*, *E.tereticornis*, *E.maidenii*	1982	Burley, *et al*, 1989
South Africa Republic	467 414	21 728	489 142	(Total)	1988	DEA, 1989, FOA, 1989, Van der Zell, 1989
	345 115	10 612	355 727	*E.grandis*		
	107 830		107 830	*E.nitens* & *E.macarthurii*		
Transkei, Ciskei & Venda	14 469	11 116	25 585	Mainly *E.grandis*		
Sudan	-	5 000	5 000	*E.microtheca* & *E.camaldulensis*	1985	Burley, *et al*, 1989
Swaziland	14 868	5 307	20 175	Mainly *E.grandis*	1989	Companies, Van der Zell, 1989
Uganda	-	11 200	11 200	Mainly *E.grandis*	1985	Burley, *et al*, 1989
Zambia	15 500	-	15 500	Mainly *E.grandis*	1985	Burley, *et al*, 1989
Zimbabwe	17 474	11 441	28 915	*E.grandis* & others	1988	For. Com. Zimbabwe, 1988
Grand Total	746 914	226 883	973 797			

Considering the countries for which no approximate areas are available, Table 1 shows that the total eucalypt estate in Sub-Saharan Africa must exceed 1 million ha of which about 75% are for commercial purposes. This should be compared with the estimated world's total of 6 million ha eucalypt plantations in 1985 of which 4 million ha are for industrial use (Jaakko Pöyry, 1987). In 1989 the world's commercial eucalypt plantations had apparently increased to nearly 5 million ha (Vigneron, 1989*) of which about 16% were in Sub-Saharan Africa.

RATE OF NEW PLANTINGS

It is even more difficult to assess the annual planting rate of eucalypt plantations, since its variation is large, afforestion projects change, targets are not achieved or the political situation allows no expansion. Worldwide plantings of eucalypts for industrial use at present are estimated at approximately 200 000 ha per year (Vigneron, 1989*). In Africa the political or economic situation in certain countries does not allow expansion, e.g. Angola, Ethiopia, Madagascar, Mozambique and Zambia, while some countries concentrate on the afforestation of softwoods, viz. Kenya, Malawi, Swaziland, Tanzania and Zimbabwe. Furthermore, as mentioned above, Benin, the Ivory Coast, Liberia, Nigeria, Zaire and others are planting mainly hardwoods other than eucalypts.

On the other hand, four countries have limited eucalypt afforestation programmes such as Burkina Faso (a target of 7 000 ha for shelterbelts and fuelwood; Zech *et al*, 1989), Comores (100 ha per year for 8 years; Burley *et al*, 1989), Swaziland (a further conversion of about 1 000 ha pine to *E.grandis*) and Zimbabwe (503 ha in 1987/88 and 2 422 ha up to 1990/91; For. Com. Zimbabwe, 1988), while only two, the Congo and South Africa have major extension programmes. The Congo intends to expand its clonal plantations by 5 000 ha per year to an initial total area of 50 000 ha and later perhaps to 75 000 ha. The commercial eucalypt plantations in South Africa, have increased by nearly 100 000 ha from 1980 to 1988, including areas converted from other species. During the last two years, 37 438 ha *E.grandis* and 12 951 ha other eucalypts were planted at an accelerated rate (Edwards, 1989). It is supposed that this latter rate must be maintained for the next five years, after which it can drop to 8 000 ha per year to satisfy future industrial demands. It is also foreseen that twice that area of woodlots will have to be planted to provide the rural population with firewood (Van der Zell, 1989).

PRODUCTIVITY OF PLANTATIONS

Projected mean annual increments of timber under bark (MAI) have seldom come up to expectations in Africa. Zech *et al* (1989) quote a case in Burkina Faso where the MAI at 8 years of a eucalypt project was expected to amount to 6-10 m^3/ha/year, but was in reality only 1,2-1,8 m^3/ha/year. The main reasons for these low MAI's are drought and poor silviculture. Under better conditions, however, they can increase to between 5 and 10 m^3/ha/year. Similar figures are given for Burundi (5-10 m^3/ha/year) and Rwanda (8,5 m^3/ha/year) (Burley *et al*, 1989). The same authors state that MAI's between 10 and 20 m^3/ha can be expected from well designed and maintained man-made forest in the lowland humid forestry areas of Africa. This depends to a large extent on the correct species selection, establishment techniques, fertilization, weed control, stocking and maintenance.

This has been shown in the Congo where the well-known clonal forestry project with eucalypts shows an average MAI of between 15 and 25 m^3/ha/year at 6 to 7 years (Vigneron, 1989^{a}), while Delwaulle (1989) quotes a maximum for certain clones of 30 m^3/ha/year under commercial conditions. In Swaziland a similar growth rate is achieved (25 m^3/ha/year) for *E.grandis* in one project under sub-tropical conditions. This is mainly due to the climatic conditions and selected stock, since in another project with the same species but under much drier conditions the MAI is hardly 15 m^3/ha/year.

In South Africa *E.grandis* has shown an amazing flexibility and adaptability, growing from tropical lowlands to temperate climates. Because of this and local soil conditions, MAI's with a range as wide as from 5 to 70 m^3/ha/year have been recorded under commercial practices. It is now generally accepted that the low values are mainly due to wrong species choice, poor soils and inadequate site preparation. On the other hand the high MAI's only occur when the climatic and soil conditions are optimal. The average MAI for *E.grandis* is below 20 m^3/ha/year and that for the other species at least 5 m^3 less. However, the latest planting will have a much better increment, owing to the improvement of site/species matching, planting stock and site preparation techniques. The actual MAI for *E.grandis* felled during 1986/87 was 19,3 m^3/ha/year, while that for the other eucalypts was 11,9 m^3/ha/year. It is confidently expected that the above improvements can increase these growth rates by up to 40%.

CONSERVATION OF NATURAL FORESTS

In the introduction it has been stated that the greatest threats to natural forest and open woodland in Africa are caused by population pressures for agricultural land and fuelwood, and the indiscriminate removal of the capital growing stock of commercially desirable forest species. The demand for fuelwood in Sub-Saharan Africa is estimated to range from 0,5 m^3/head/year in Burkina Faso (Zech *et al*, 1989), 0,78 m^3/head/year in Benin (Drechsel and Schmall, 1990) to over 2 m^3/head/year, Tanzania (Gandar, 1983). Even at the lowest rate, this would amount to an annual demand of about 250 million m^3 of wood for fuel and other purposes in rural areas. In South Africa alone this is estimated at 10 million m^3 (Van der Zell, 1989). The MAI of unmanaged tropical forest is by definition nil (Anon, 1987^{b}), while the effect of active management is estimated to increase this to <1 m^3/ha/year in Burundi, 1,5 m^3 in Tanzania and 6,5 m^3 in Rwanda (Burley *et al*, 1989). These authors estimate the MAI of savanna forests in Tanzania at 0,15 m^3/ha/year. If an average MAI of 2,5 m^3/ha/year could be assumed, this means that the increment of 100 million ha or about 20% of the existing forests in Sub-Saharan Africa are required to satisfy the fuelwood demand, without destruction of the forest resource. On the other hand, if this demand would be met from woodlots or fuelwood plantations, the present areas (Table 1) should be increased at least hundredfold.

The picture for the sustained supply of industrial timber is even less comforting. As a result of over-exploitation of valuable timber species, large scale destruction has taken place to such an extent that the state of forests in Benin, the Ivory Coast, Nigeria, Senegal and Togo can only be described as critical. Attempts of intensive management and regeneration in Ghana, the Ivory Coast, Nigeria, Uganda and Zaire have all been abandoned or discontinued. Plantations of many different hardwood species have been established, but their growth rate is generally low. Contributions by fast-growing eucalypts, mainly *E.grandis*, remain small since short rotations supplying pulpwood are generally more profitable. Eucalypt plantations grown on longer rotations for sawlogs, veneer and transmission poles occur virtually only in South Africa (30 594 ha, DEA, 1989) and Zimbabwe (11 830 ha, For. Com. Zimbabwe, 1988).

The only recent case found in literature of actively protecting natural forests by man-made plantations was the planting of a protection belt around 40 000 ha of these forests in Burundi (Burley *et al*, 1989). It serves partly as a soil conservation project and consists amongst others of eucalyptus species. It is thus evident that eucalypt plantations could play a meaningful role in decreasing the forest destruction and degradation in Sub-Saharan Africa. However, large scale reforestation with fast-growing species has to be undertaken in order to make some impact on deforestation, and it must be combined with intensification of the management of the remaining natural forests.

IMPACT OF RESEARCH

The research efforts for eucalypt plantations in Sub-Saharan Africa have been in general limited, unco-ordinated (even in the same country) and often interrupted for many different reasons during periods of instability. In most countries research on pines has received preference but lately there has been a swing of activity towards eucalypt research, especially for short-rotation crops. Particularly in the fields of tree breeding, species trials, provenance testing, hybridization, plant propagation, protection and basic silvicultural techniques great strides have been made. Results are tested in many countries for adaptation to local conditions. This section does not intend to give a comprehensive review of the successful research results which have been obtained, but will highlight only two cases where research had a significant impact on the development and improvement of eucalypt plantations.

This research impact is distinctly apparent in the Congo and South Africa. Between 1972 and 1974 the vegetative propagation of eucalypts was developed in the Congo and its practical application tested. From 1978 reforestation took place with this clonal material and with an initial target of planting 25 000 ha. This target has been reached and extended now to 50 000 ha. Originally natural hybrids were used, but further research and an artificial hybridization programme has made this project a great success with continuous improvements.

In South Africa the impact from intensive research on the growing of eucalypts is more general. Tree breeding with *E.grandis* started in the early 1960's so that improved seed is now freely available. Silvicultural research in the fields of nursery techniques, site preparation, nutrition, regeneration, thinning and weed control was intensified in the early 1970's, followed by soil and site investigations. In 1983 a start was made with clonal propagation, site/species investigations and a selection and breeding programme for more cold-tolerant eucalypts. The greatly increased demand for hardwood pulpwood, the scarcity of additional land and the planting of more marginal sites has made the increase of productivity per unit area necessary. Selected seed, proper site/species matching, improved nursery techniques, intensive site preparation, correct fertilizing, thorough weed control and lately clonal material has enabled the forest industry in South Africa to increase its productivity. It is estimated that as a combined result this improvement can amount to at least 40%. However, fear is expressed that intensive silviculture can lead to early exhaustion of sites, especially under marginal conditions.

FUTURE SCENARIO

Future developments depend to a large extent on socio-economic conditions as well as those of available sites. Eucalypt plantations have a great future in Sub-Saharan Africa as industrial plantations on deforested land and as fuelwood plantations and woodlots. It is expected that further expansion of industrial eucalypt plantations will mainly be for the production of pulpwood. This is stimulated by the changing ratio, world wide, of softwood to hardwood intake for paper production in favour of hardwood. In South Africa it has been estimated that, in order to supply the forecast demand, new establishment of eucalypt plantations over the next 20 years should be more than 200 000 ha or about 50% of the existing estate (Van der Zell, 1989). It is thought that growing conditions favourable for eucalypts exist in many other countries and it would be possible to start projects similar to that in the Congo. The main constraints for such developments are lack of the necessary infrastructure, skills and capital, and the general pattern of land tenure in Africa.

It has been shown that the demand for fuelwood in Africa is enormous. To satisfy this, large areas of fuelwood plantations and woodlots would be necessary without further destruction of natural forests and open savannas. Eucalypt species can play an important role in the supply of fuelwood, but it is thought that amongst others in drier areas *Acacia*, *Cassia* and *Prosopis* spp and in humid areas *Gmelina arborea* and *Leucaena leucocephala* may be preferred for local demands and conditions. Burley *et al* (1989) expressed the opinion that the competition between agriculture and forestry should be minimal since man-made plantations produce at least five times as much as the original forest or savanna. However, under African conditions the application of one of the various agroforestry systems may be a more desirable solution for the production of fuelwood and building material.

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FOREST RESEARCH AND WOOD SUPPLY IN BRAZIL

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FDC: 238: 176.1 Eucalyptus spp.: 721.1: 62: (81)

SUMMARY

Among the South American countries, only Brazil and Chile have developed significant reforestation activities for industrial uses. However, the levels of wood consumption are many times larger than their present man-made forests can supply. The gap has been filled with timber harvested from the natural forest reserves. In order to release the pressure on natural forest ecosystems, man-made forests need to be increased both in planted area and productivity. Research to generate new technology is essential but it has not been sufficient yet to enhance wood supply at desirable levels. More efficient management methods and the use of more productive genetic stocks must be extended to the rural communities across the countries. Important marketting opportunities must be oppened in order to establish dependable production forestry operations.

INTRODUCTION

Man has always used forest products. Even with the advancement of the industrial age and the development of new materials, forest products, mainly wood for fuel and for structures, have continued under high demand.

In less developed countries, the main form of wood utilization is as fuelwood and as construction material. In many regions in the world wood is in short supply even for these uses. This situation tends to worsen with human populational growth, predominantly in the tropical regions.

Among Latin American countries, only Brazil and Chile have adopted reforestation practices to suply industrial requirements (CONTRERAS 1988).

Chile has over 1.2 million hectars of man-made forests, 5% (63,847 ha) of which is planted to *Eucalyptus*, mainly *E. globulus* subsp. *globulus* (BARROS 1989), for sawtimber, veneer, pulp and other products. Eucalypt plantation area in Colombia is much smaller. Less than 4.000 hectars is dedicated to pulp production in that country (SMURFIT CARTON DE COLOMBIA, mimeograph).

The oil crisis in the seventies forced many industries in Brazil to switch from oil to wood for energy. Moreover, this country has thousands of iron smelters which depend on charcoal.

Iron and steel producers in conjunction with the booming pulp and paper industries are the most important users of forest products in Brazil, using mostly eucalypts and native harwoods. In spite of an intensive reforestation effort which has generated approximately 6.6 million hectars of plantation in twenty years (CHERKASSKY 1988), the wood from planted forests still supplies less than a quarter of the country's need. According to estimates by the Brazilian Society of Silviculture, the planted forests have supplied only 64 million of the 267 million cubic meters demand in 1987. The remaining 203 million cubic meters were harvested from natural forests.

Although up to 73% of the wood consumption in Brazil have been in the form of fuelwood and charcoal for energy, other sectors are also increasing their demand of wood at fast rates. Many pulp and paper mills in Brazil are expanding their production capacity, certainly leading to serious shortages of raw material in the near future. According to CHERKASSKY (1988), the pulp and paper industries alone will require an additional ten million hectars of reforestation with fast growing tree species by the end of the present decade. A roughly equal amount of raw material will be required by other industrial sectors. Therefore, wood supply will soon become critical.

In order to prevent further destruction of the native forests and still sustain industrial output, it is necessary to increase not only the reforestation area but also the productivity of every planted hectar. To increase the extent of reforestation is a matter of operational management decision. However, a lot of research effort is necessary to increase the forest productivity.

Research in forestry has multiple purposes. The most important is to increase the wood volume production per unit of time and area and, simultaneously, to improve the quality of the raw material. Another important goal in forestry research is the conservation of natural forest ecosystems. Less natural forests will need to be devastated if planted forests are made more profitable. Forest research has a lot to do with social aspect as well. In many regions where environmental conditions are unsuitable for agriculture, profitable tree farms may be established by applying new technologies and using proper genetic material. Such farms can create job opportunities for rural workers, encouraging them to make their living at the site of the forestry operation, instead of migrating to socialy problematic spots at the outskirts of urban centers.

THE ROLE OF RESEARCH IN THE SUPPLY OF WOOD PRODUCTS

GOLFARI et al. (1978) have surveyed regional climatic patterns in Brazil and assessed the performance of tree species included in field trials and plantations. Based on data gathered throughout the country and on climatic analogies between donor and receptor sites, these autors have tentatively assigned groups of species to regions where these could more likely succeed. Such basic information was extremely useful for the expansion of forestry operation across new regions because it helped to narrow the list of species to be included in further trials. Not only species within such groups but also provenances within species have shown remarkably variable perfomances in test plantations. It is important to recognize this variability in order to reduce the risk of losses in large scale operations.

Almost all commercial eucalypt forests in Chile are planted to *E. globulus* subsp. *globulus* of unknown genetic base. Moreover,this species suffers significant losses in harsh drought and frost areas. Recent efforts are concentrated on further species and provenance trials. Alternative species of potencial value such as *E. nitens*, *E. delegatensis* and *E. camaldulensis* are being studied.

Eucalyptus grandis, *E. camaldulensis* and *E. urophylla* are all tropical species. The first tends to produce comparatively higher wood volume in good quality sites. Nevertheles, its productivity declines faster on low fertility soils (RODRIGUES et al. 1986). This fact indicates that *E. grandis* can respond readily to site improvement. In fact, according to SUITER FILHO et al. (1980) a 14-month old *E. grandis* stand planted at a subsoiled and harrowed site has produced 112% more wood volume than when planted at an unprepared site. Likewise, site improvement through higher technology input, such as complete site preparation complemented with fertilizer application, has shown a dramatic response in *E. grandis*. The response was lower in *E. camaldulensis* and lowest in *E. citriodora* (BILA 1988). The differential responses are most likely related to the root architecture of these species.

The root system of *E. grandis* is superficial while *E. camaldulensis* presents both superficial and deep roots (KREJCI et al. 1986). Species with more vigorous root system, such as *E. camaldulensis*, are more likely to adapt to a wider range of site conditions and should be preferred in low technology input operations. *E. grandis* should be chosen only where high technology input operation is feasible.

Biotic factors are also a key factor in the choice of species for reforestation. For example, although being highly productive, species like *E. grandis* should be used with caution because of its high susceptibility to stem canker, leaf rust and other diseases (FERREIRA 1986).

Insects are another important limiting factor to forestry. Especially in the tropics, leaf-cutting ants are a serious problem and can ruin the whole operation in a matter of days if not properly controlled. However, given that these insects are well known and cause damage to almost all eucalypts and other tree species, their control has become a regular operational procedure. On the other hand, insects like *Thyrinteina arnobia* Stoll sometimes can cause serious losses by defoliating the trees. OLIVEIRA et al. (1984) observed that the damages caused to *E. grandis* and *E. saligna* were more intense than those caused to *E. urophylla* and *E.cloeziana*. *E. camaldulensis* was the least susceptible among these species. A survey by ANJOS et al. (1986) has revealed losses of up to 25.6 m3/ha due to *T. arnobia* in a 400.000 hectar plantation of *E. grandis*. These autors also mention losses in the order of 64.7% in an area of 40 hectars of *E. grandis* due to *Timocratica albella* stem borer.

SANTOS et al. (1985) have shown that other insects such as *Apatelodes sericeae* Schaus severely defoliated *E. grandis*, *E. saligna* and *E. urophylla* over an area of several hundred hectars in the States of São Paulo, Minas Gerais, Mato Grosso do Sul, Espírito Santo and the Federal District in Brazil.

These aspects add to the complexity of tree species selection for reforestation. Therefore, choosing species based on their growth potential *per se* can lead to disastrous decisions in forestry operations. There is no question that the low yield of many man-made forests when using exotic species is due to their inability to cope with the climatic and biotic adverse effects. Examples on these are reported by RICHARDSON & MEAKINS (1986) in South Africa. The use of fast growing *E. viminalis* had to be abandoned in that country due to its suceptibility to *Gonipterus scutellatus*. Similarly, we should mention the failure of *E. grandis* in the humid tropical regions in Brazil due to stem canker disease.

Striking variability also exist among provenances in a number of economically important traits such as growth rate (BRASIL et al. 1986; VENKATESH & KANANJI 1985; PIRES & PARENTE 1986; PURNELL & LUNDQUIST 1986), susceptibility to insects (ZANI FILHO et al. 1984) and diseases (PURNELL & LUNDQUIST 1986; FERREIRA 1986). The use of such variation is fundamental to maximize the profitability of forestry operations.

The quality of the wood produced is quite often overlooked when introducing exotic tree species. In some cases, fast growth rates are associated with lower wood density (ALBINO 1983). The same way, the outstanding resistance to drought and stem canker found in *E. torelliana* does not encourage its use because of the very poor quality of the pulp produced by this species (MACHADO et al. 1986).

Man-made forests, especially when eucalypts are used, are subject to a number of silvicultural treatments in order to enhance wood volume production and, consequently, the profitability of the operation. It is therefore important to know how these treatments affect the wood quality and to decide on the most suitable management practices.

Brazilian soils as well as most soils in the tropical regions in South America are generally poor in nutrients, especially phosphorus. With the tendency to crop the trees on a shorter rotations, substantial amounts of nutrients are removed at faster rates. POGGIANI (1985) estimated the content of 219 Kg of nitrogen, 58 Kg of phosphorus, 190 Kg of potassium, 954 Kg of calcium and 81 Kg of magnesium per hectare in the biomass of an eleven-year old stand of E. saligna. Even if only the stem is harvested, it accounts for roughly 62% of the total nitrogen, 63% of phosphorus, 72% of potassium, 72% of calcium and 65% of magnesium that are removed (POGGIANI et al. 1983). Therefore, replenishment of these vital elements is essential not only to increase the site quality but also to maintain the productivity in future rotations.

Many eucalypt species coppice after felling. Since each stem produces a number of shoots, there used to be an expectation that the first coppice crop would produce a higher volume than the original stand. However, under normal circumstances, up to 30% of the trunks fail to sprout and leaf-cutting ants can kill a large number of coppice stumps. In addition, smaller diameter trunks tend to produce less vigorous sprouts (PEREIRA & BRANDI 1981). Therefore, under a short rotation production system each coppice crop tends to yield less than the previous harvest and, eventually, a total replanting of the area is required.

In spite of high costs involved, the renewal of the stands provides an opportunity to review the road system and to apply good soil fertilization and conservation practices. This way new crops can be harvested more efficiently. Moreover, it permits the restocking of the land base with a much higher-yielding genetically improved material. In summary, coppice rotations do not appear to be much advantageous under high technology input systems.

Volume productions in the range of 40 to 60 m3/ha year have been achieved through operations involving high technology input. However, such high technology operations are not of general access throughout the land under reforestation. Most of these areas are located in remote regions where even the basic maintenance operations have been ignored.

Reports from a survey on the yield of eucalypt reforestation in Minas Gerais, where most of the Brazilian eucalypt plantations are located, have shown that the average yield falls in the range of 5 to 14.5 m3/ha/year (ALFARO et al. 1986) at the age of seven years. These are exceptionally low yields for eucalypts and certainly can be dramatically increased by applying basic silvicultural and management practices such as minimum site preparation, fertilization, and the control of weed and leaf-cutting ants. The use of genetically improved seed, hybrids and mass vegetative propagation of exceptionally vigorous stocks by means of micropropagation and other propagation techniques should also be emphasized for the enhancement of productivity in eucalypt plantations.

TECHNOLOGY AS A FACTOR OF FORESTRY DEVELOPMENT

It is out of question that research is fundamental to develop new technology and to generate higher yielding genetic stocks. However, research by itself is certainly not enough to inflict substantial changes on the wood supply figures for the whole country. Both forest extention efforts and the creation of wood marketing opportunities throughout the reforestation areas need to be emphasized. These initiatives would encourage a larger portion of the rural community to participate actively by establishing tree farms as an alternative activity and thereby contribute to the overall development of productive forests across the country.

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ACTINORHIZAL PLANTS: UNDEREXPLOITED TREES AND SHRUBS FOR FORESTRY AND AGROFORESTRY

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SUMMARY

Actinorhizal tree and shrub species actively fix nitrogen in the environments in which they grow. As a result of this activity they contribute significantly to soil fertility and early soil development. Use of actinorhizal species could improve forest production and would be especially valuable in agroforestry programs. Actinorhizal species have been under-exploited in comparison to nitrogen-fixing legume tree species for a number of reasons. However, with the accumulation of additional basic research information about actinorhizal species, their use will justifiably increase in the future.

Keywords: Actinorhizal trees, *Frankia*, nitrogen-fixation

INTRODUCTION

Actinorhizal plants are woody shrub and tree species which have a symbiotic association with the nitrogen-fixing actinomycete, *Frankia*. Twenty-four genera (Table 1), with over 160 species, are currently recognized to be actinorhizal. It is possible that other genera and species will be discovered to be actinorhizal in the future, but little research is being undertaken in this regard. Also, actinorhizal trees have received much less attention in forestry and agroforestry than legumes during the past decades. This is in part due to the relative ease with which *Rhizobium* can be handled, but also to the basic information which have arisen out of studies of agriculturally important herbaceous legumes. Actinorhizal trees have great potential and additional use should be made of them in the future.

In natural ecosystems, actinorhizal species are generally considered pioneers, inhabiting nutrient poor areas in early site development, and becoming less important and less competitive as soil fertility increases (Goldman 1954, Lawrence et al. 1976, Vitousek and Walker 1989). They play a major role in soil nitrogen accretion (Voigt and Steucek

1969, Van Cleve et al. 1971) and also in organic matter accumulation. Thus they contribute to early soil development.

Table 1: Actinorhizal plant genera and their distributions

Genera	No. of Species	Family	Locality
Allocasuarina	54	Casuarinaceae	Australia
Alnus	47	Betulaceae	N. America, S. America & Eurasia
Casuarina	16	Casuarinaceae	Australia & Oceania
Ceanothus	31	Rhamnaceae	North America
Cercocarpus	4	Rosaceae	North America
Ceuthostoma	2	Casuarinaceae	Australia
Chamaebatia	1	Rosaceae	North America
Colletia	4	Rhamnaceae	South America
Comptonia	1	Myricaceae	North America
Coriaria	16	Coriariaceae	N. America, S. America & Oceania
Cowania	2	Rosaceae	North America
Datisca	2	Datiscaceae	N. America & Asia
Discaria	5	Rhamnaceae	Oceania
Dryas	1	Rosaceae	N. America & Eurasia
Elaeagnus	38	Elaeagnaceae	N. America & Eurasia
Gymnostoma	18	Casuarinaceae	Australia & Oceania
Hippophae	2	Elaeagnaceae	Eurasia
Kentrothamnus	1	Rhamnaceae	South America
Myrica	28	Myricaceae	N. America, Eurasia, & Africa
Purshia	2	Rosaceae	North America
Retanilla	2	Rhamnaceae	South America
Shepherdia	2	Elaeagnaceae	North America
Talguenea	1	Rhamnaceae	South America
Trevoa	2	Rhamnaceae	South America

A few actinorhizal species exist in the understory of coniferous forests, e.g. *Ceanothus, Myrica* and *Shepherdia*. In these sites they also may contribute significant amounts of nitrogen which benefit the dominant species (Binkley et al. 1982). Silvicultural management schemes which could take advantage of this role should be investigated in the future.

ACTINORHIZAL SPECIES OF CURRENT IMPORTANCE

Although actinorhizal plants contribute significantly to a major number of ecosystems throughout the world, direct utilization by humans is restricted to only a few members of this large group. Table 2 summarizes the few species which have been exploited on a large scale. In the following section I shall provide additional information on these and other actinorhizal species which I feel have good potential for further investigation.

Table 2: Actinorhizal plants of economic importance

Plant	Product/Use	Country
Alnus rubra	paper pulp	United States
Casuarina equisetifolia	fuelwood	China, India, etc.
Casuarina junghuhniana	poles	Thailand
Casuarina oligodon	coffee shade	Papua New Guinea
Elaeagnus spp.	nurse species	United States
Hippophae rhamnoides	fruit juice	China
Myrica rubra	fruit	China

The genus *Alnus*, alder, is of greatest importance in the temperate regions of the world. Alders range in size from small shrubby trees to large timber species reaching heights in excess of 30 meters. They produce a moderately hard wood that is especially good for fuelwood, as well as being desirable for fine furniture production. Pulp made from alder wood is excellent, although because of pigments it requires bleaching (Hrutfiord 1978), and the fiber length complements that of softwood species for paper production (Leney et al. 1978). In some tropical montane areas, evergreen alders (e.g. *Alnus nepalensis*, *Alnus jorullensis*) are managed by humans for watershed and pastoral management as well as for wood and fuelwood production (Dawson 1986). *Alnus nepalensis* wood is desirable for matchstick production.

Casuarinas, recently taxonomically revised into four separate genera, were widely distributed by humans during the past few centuries into most tropical areas of the world. These trees are probably the most exploited of all actinorhizal species, and they are surely the most widely planted actinorhizal tree of the tropics. Despite a diversity of over 80 species, only 3-4 have been utilized extensively. *Casuarina equisetifolia*, the most commonly grown species is cultivated widely for poles and fuelwood production (National Research Council 1984). Its extremely dense wood of high calorific content makes it a most desirable species for charcoal production. Large plantations are maintained in India, China and other southeast Asian countries. *Casuarina junghuhniana* plays this same role in Thailand. *Casuarina cunninghamiana* and *C. glauca* have been introduced into numerous countries as well, but are used to a lesser extent. Casuarinas have the important characteristic of being able to survive and even thrive in soils of high salt content, or those inundated with seawater. For this reason they have been adopted for stabilization of dune areas along seacoasts. Little research has been directed to the species of *Gymnostoma* or *Allocasuarina*, relatives of *Casuarina* (*sensu stricto*) in the Casuarinaceae. *Gymnostoma* has good potential as a fuelwood species, but has not been cultivated widely outside of its native Australia. *Allocasuarina* species are generally inhabitants of desert regions and might be suitable for arid or salty sites.

Like the casuarinas, *Elaeagnus* species have been distributed widely by humans during the past few centuries. *Elaeagnus umbellata* (autumn olive) and *E. angustifolia* (Russian olive) have been introduced into a large number of countries in the temperate zones. Other semi-tropical species likewise have been introduced. The primary purpose for *Elaeagnus* introductions has been for soil conservation and stabilization purposes. However, another major factor in their promotion has been the edible fruits which are favored by many bird species, making them desirable for amenity planting (Fessenden 1979). *Elaeagnus* makes a very useful nurse species for high value timber production. It has been shown to significantly improve growth of the temperate hardwood species, *Juglans nigra*, in the central United States (Funk et al. 1979, Friedrich and Dawson 1984). Because it attains a maximum height of only about 5-6 meters, it does not significantly compete with the prime species in mixed plantations.

Hippophae, a close relative of *Elaeagnus*, produces an edible fruit which is relatively high in vitamin C. In China this abundant fruit is harvested and processed into a juice which is bottled and distributed widely throughout the country. Fermentation of the juice is also practiced and an alcoholic beverage is produced both in China as well as other countries such as Finland.

Shepherdia, another close relative of *Elaeagnus*, shares a number of the same characteristics of *Elaeagnus* as well as *Hippophae*. It produces a small fruit like that of *Hippophae* and likewise could be utilized for juice.

A number of the tropical species of *Myrica* also produce an edible fruit which may be harvested by humans. One such fruit is that of *Myrica rubrum* which is cultivated in the tropical areas of southern China and adjacent areas of southeast Asia. The fruit is approximately 3 cm in diameter, and has a single stony seed in the center. It has a pleasant taste, not unlike that of a plum. In China it is routinely preserved in a sweet syrup and distributed throughout the country as a canned fruit.

Wider adoption of these actinorhizal species for tangible products could be made throughout the world where economic incentives exist. The use of nitrogen-fixing species for production of wood or fruits might be advantageous for environmentally sound reasons also. If such species are managed carefully, nitrogen fertilization may not be necessary even while producing high yield. The important aspect of this strategy is to verify the amount of nitrogen (or more appropriately the proportion) derived from nitrogen-fixation.

Before proceeding with further discussion of the desirable value of nitrogen-fixing species in forest plantations or agroforestry programs, I feel that it is important also to give a cautionary note about using actinorhizal plants or any similar nitrogen-fixing species that is adapted as a pioneer species. Any pioneer species, and in particular nitrogen-fixing pioneers, are highly competitive in their environments because of nutritional advantages which they gain from their symbioses and because of their rapid rates of growth. Due to these competitive tendencies, introduced exotic nitrogen-fixing tree or shrub species have become pests in some ecosystems. Often the species move away from the plantation and invade adjacent areas because of seed distribution via herbivores (Vitousek and Walker 1989). *Myrica faya* has spread widely in Hawaii, *Elaeagnus* species have spread widely in the central U.S. and *Casuarina* has spread throughout southern Florida. The distributions of all of these genera have increased because of heavy seed production and dispersal by animals. Thus, I believe it is timely to undertake cultivar selection programs aimed at developing sterile hybrids, male-only nursery stock or non-fruiting cultivars.

FRANKIA INOCULUM AVAILABILITY

Effective, pure-cultured *Frankia* inocula for all of the genera highlighted above are readily available from research laboratories around the world. There is no valid reason for not routinely inoculating actinorhizal plants in nurseries for plantation purposes of any kind. Inoculation assures that *Frankia* will be present in sufficient quantity to produce adequate nodules for symbiotic nitrogen-fixation. In addition most *Frankia* have been evaluated preliminarily for nitrogen-fixation performance and usually the most efficient strains will have been chosen for inoculum. Despite this research effort, inoculation with pure-cultured *Frankia* is commonly omitted in nurseries and plantations. Often soil populations of *Frankia* may not be adequate to insure maximum nodulation and nitrogen-fixation. Also, soil populations may not be as efficient as elite pure-cultured bacteria. It seems most important to encourage the use of *Frankia* inoculum in the majority of cases at all times.

ASSESSMENT OF NITROGEN FIXATION IN ACTINORHIZAL SPECIES

The contribution of nitrogen fixation to a plant's growth theoretically might be 100% of its nitrogen demand, if physiological factors were not inhibitory and total biomass yield was not to be maximized. In the real world however, maximum biomass production is desired, and rarely are environmental conditions optimal for nitrogen fixation. As a result of these factors, the contribution of nitrogen fixation to total plant nitrogen demand is less than 100%. In studies of other nitrogen fixing trees, the contribution was closer to 50% in real terms (Baker 1990).

Some estimates of total nitrogen fixed by a few actinorhizal plants have been published. These are summarized in Table 3. In comparison to other nitrogen-fixing tree species, the estimated fixation rates are similar. Whether this amount of nitrogen fixed accounts for a small or large proportion of all the nitrogen which the plant requires is unclear from most studies. Gauthier et al. (1985) calculated that 49-55% of the nitrogen required by *Casuarina* was obtained from nitrogen-fixation in their study. If a 75% value for the proportion of nitrogen fixed was possible to obtain by management strategies or by cultivar and/or strain selection, significant nitrogen increases might be realized in some ecosystems.

Table 3: Estimated contribution of nitrogen-fixation for some actinorhizal species

Species	Nitrogen Fixation[a]	Reference
Alnus rubra	320	Newton et al. 1968
Casuarina equisetifolia	40-60	Gauthier et al. 1985
Myrica faya	18	Vitousek and Walker 1989

[a](expressed as kg ha^{-1} yr^{-1})

Species and cultivars of nitrogen-fixing trees, and strains of their microsymbionts differ in the efficiency of fixing nitrogen. Selections of highly efficient cultivars or strains could be made to increase the amount of nitrogen fixed in a particular ecosystem. Also, any method which would decrease the amount of available nitrogen in the soil environment surrounding nitrogen-fixing trees would be expected to increase nitrogen-fixation by eliminating inhibitory concentrations of combined nitrogen. Interplanting non-fixing, nitrogen-demanding species along with nitrogen-fixing trees may result in increased nitrogen-fixation. Although such silvicultural methods may be proposed to increase nitrogen-fixation in theory, benefit may not be gained in practice.

For optimal management of nitrogen-fixing actinorhizal species (or any nitrogen-fixing species), the importance of nitrogen-fixation must be weighed against the costs in carbon (photosynthate) to the plant. In absolute terms, the cost of nitrogen-fixation to the plant is more than that of nitrogen assimilation from the soil. Thus under most situations, a nitrogen-fixing species will only fix atmospheric dinitrogen when combined forms of nitrogen are limiting in the soil. If nitrogen fertilization is not prohibitively expensive, addition of nitrogen fertilizer may significantly increase yields. If nitrogen fertilization is expensive, on the other hand, then methods to optimize nitrogen-fixation are warranted.

Because of the points briefly raised above, a simple procedure for the assessment or quantification of nitrogen fixation is desirable. Such a procedure would roughly determine the proportion of nitrogen derived from atmospheric nitrogen in contrast to that obtained from soil sources. Some existing techniques for estimating nitrogen-fixation are possible candidates for such work (e.g. nitrogen balance studies, ^{15}N-dilution studies). A documented procedure is not currently available however, nor is sufficient research being conducted to provide the basic information necessary before silvicultural management studies are initiated.

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NITROGEN-FIXING TREES; VALIDATION AND PRIORITIZATION

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SUMMARY

A summary table is provided of 648 trees and large shrubs that have been validated as nodulating, and known or presumed to fix nitrogen. Conflicting results are associated primarily with the caesalpinioids. The summary is derived from NFTA's expanded database, available in sections on disk, that includes about 1500 taxa and 80 fields of information. The N-fixing tree species (NFTs) are assigned priorities A through D on the basis of their economic use and ecological significance. Fifty species are tentatively assigned to the highest priority 'A', and these are described briefly.

The 648 NFT species represent 9 families. They are dominated by the 519 legumes, including the 321 mimosoids, 173 papilionoids and 26 caesalpinioids. It also includes non-legumes of the families Betulaceae (38 spp), Casuarinaceae (20 spp), Coriariaceae (16 spp), Elaeagnaceae (10 spp), Myricaceae (14 spp), Rhamnaceae (14 spp), Rosaceae (5 spp) and Ulmaceae (8 spp). N-fixation is based on rhizobia (legumes, Ulmaceae) and actinomycetes of the genus Frankia (all other families). A single evolutionary line is proposed for these N-fixing families. NFTA invites use of this database and information on lesser-known species in this list.

DISCUSSION

Trees and shrubs that are known to nodulate and presumed or known to fix N are listed in Appendix Table 1. The list presently includes 648 species, representing 115 genera and 9 dicotyledonous plant families. The genus Acacia is represented the most frequently, by 193 species. All woody species that can attain 3 m in height, whether single or multiple-stemmed, are included in NFTA's definition of a tree. Shrubs often fill important ecological niches as a result of their ability to fix nitrogen. Only one family that includes nodulating plants, the Datiscaceae, does not appear here, as the genus Datisca lacks arboreal or woody forms.

The complete NFTA database presently comprises about 1500 species. The full data base includes about 80 fields of information. This also includes a class of nodulating subshrubs and vines, a class of trees suspected (by relationship) but not known to nodulate, and a class of non-nodulating leguminous trees. As calculated by de Faria et al. (1989), nodulation characterized 23% of 349 tested caesalpinioid species, 90% of 454 tested mimosoids and 97% of the 2592 tested papilionoids. Primary published resources for biological N-fixation include the classic work "The Leguminosae" by Allen and Allen (1981), and recent summaries by de Faria et al. (1989) and D. Baker (1989). The NFTA database incorporated all data from the earlier works of Halliday (1984). It may be conjectured from relationships that several thousand more species of trees and shrubs will be found to be N-fixing.

The genera of N-fixing trees and shrubs (NFTs) are summarized in Table 1. Most of the 115 NFT genera are legumes, with 19 caesalpinioids (abbreviated Caes in the table), 26 mimosoids and 55 papilionoids. Data are presented in Table 1 for the numbers of confirmed NFTS and the total number of species in each genus. In very few instances have the genera been fully studied. The total numbers of N-fixing species--herbaceous and woody--in leguminous genera have been summarized by de Faria et al. (1989).

Phylogenetic relationships of NFTs based on Cronquist (1988) show two distinct evolutionary lines in the dicots. One line originates in the Rosales and includes the legumes and Rosaceae, the Elaeagnaceae of Myrtales, and the Rhamnaceae of Rhamnales. The other line originates in the Magnoliales by way of the Hamamelidales, and includes the families Myricaceae, Betulaceae, Casuarinaceae and Ulmaceae. The Coriariaceae is a family allied to Ranunculales, but of disputed ordinal location (Cronquist 1988). The argument has been made that the Hamamelidales could have a Rosidean origin, and this would link all NFTs into a monophyletic origin. A less conservative view would be polyphyletic. Based on these phylogenetic relationships, other plant orders that might be suspected to include N-fixing species are the Hamamelidales, Juglandales and Leitneriales.

Nodulation involves symbiosis with rhizobial bacteria in the legumes and in the genus Parasponia and possibly other taxa in the Ulmaceae (Aspiras and Cruz, 1988). All other non-leguminous genera are nodulated by actinomycetes of the genus Frankia.

The NFTs of Appendix Table 1 have been classified A through D ranking their significance to man or their ecological importance. Fifty species were tentatively ranked "A" as species of major economic or ecologic significance. These species are summarized in Table 2, together with their major uses. A more complete description of uses and properties, origin and ecology, botany and constraints of the NFTs is available on disk from NFTA, which invites contributions and criticism of this database.

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Table 1: Genera of N-fixing trees

Family (Subfamily) Genera (Nos. of species*)

BETULACEAE: Alnus (38/38)
CASUARINACEAE: Allocasuarina (11/20), Casuarina (8/45), Gymnostoma (1/2)
CORIARIACEAE: Coriaria (16/16)
ELAEAGNACEAE: Elaeagnus (10/45), Hippophae (1/3), Shepherdia (2/3)
LEGUMINOSAE:
CAESALPINIOIDEAE: Brownea (1/30), Chamaecrista (2/250), Colvillea (1/1), Cordeauxia (1/2), Dialium (1/40), Dicymbe (2/13), Dimorphandra (2/25), Eperua (1/14), Erythrophleum (2/9), Gossweilerodendron (1/2), Hardwickia (1/1), Lysidice (1/1), Maniltoa (1/20), Melanoxylon (1/3), Moldenhauera (1/6), Mora (1/6), Saraca (1/8), Sclerolobium (3/35), Tachigali (2/24)
MIMOSOIDEAE: Acacia (193/1200), Albizia (30/150), Anadenanthera (2/2), Calliandra (11/200), Cathormion (1/15), Cedrelinga (1/1), Dichrostachys (3/12), Entada (3/30), Enterolobium (3/5), Faidherbia (1/1), Inga (14/350), Leucaena (13/13), Lysiloma (1/35), Mimosa (3/400), Newtonia (1/11), Parapiptadenia (1/3), Paraserianthes (1/5), Parkia (5/40), Pentaclethra (1/2), Pithecellobium (11/200), Plathymenia (1/4), Prosopis (15/44), Pseudopiptadenia (1/8), Schleinitzia (1/4), Stryphnodendron (2/20), Wallaceodendron (1/1)
PAPILIONOIDEAE: Aeschynomene (2/150), Andira (6/20), Baphia (1/60), Bolusanthus (1/1), Brya (1/4), Cajanus (1/2), Calpurnia (5/6-8), Caragana (4/80), Chamaecytisus (1/30), Chordospartium (1/1), Clathrotropis (2/6), Clitoria (1/70), Craibia (1/10), Cyclolobium (1/5), Dalbergia (17/100), Dalbergiella (1/3), Dalea (1/160), Desmodium (including Codariocalyx and Ougeinia) (4/300), Dewevrea (1/2), Dicymbe (2/13), Erythrina (26/108), Eysenhardtia (1/10), Flemingia (2/30), Geoffroea (1/3), Gliricidia (2/3), Hymenolobium (1/10-15), Indigofera (1/700), Laburnum (4/2-6), Lonchocarpus (8/150), Maackia (1/8), Machaerium (2/120), Medicago (1/50), Millettia (5/90), Mundulea (1/15), Myrocarpus (1/4), Myroxylon (1/2), Olneya (1/1), Ormosia (5/100), Ostryocarpus (2/6), Pericopsis (2/3), Piscidia (1/7), Platymiscium (3/20), Poecilanthe (2/7), Psorodendron (1/12), Pterocarpus (12/20), Robinia (3/4), Sesbania (6/50), Sophora (7/50), Swartzia (8/135), Sweetia (1/1), Tephrosia (1/400), Tipuana (1/1), Virgilia (1/2), Wisteria (4/6), Xanthocercis (1/2)
MYRICACEAE: Comptonia (1/1), Myrica (13/35)
RHAMNACEAE: Ceanothus (14/55)
ROSACEAE: Cercocarpus (4/20), Purshia (1/2)
ULMACEAE: Aphananthe (1/5), Celtis (2/80), Parasponia (3/6), Trema (2/30)

* First value is the number of species validated as NFTs (Appendix Table 1); second is number of species in the genus.

Table 2: Fifty major NFTs with their primary uses.

- *Acacia auriculiformis* (fuel, pulpwood, timber, ornamental), *A. mangium* (pulpwood, timber), *A. mearnsii* (tannin, pulp, charcoal, shelterbelt, poles, fuel), *A. nilotica* (fuel, charcoal, tannin, fodder (pods), leaves, gum), *A. polyacantha* (wood, fodder, soil stabilization), *A. saligna* (fuel, soil stabilization), *A. senegal* (gum arabic), *A. tortilis* (fodder (pods), fuel)
- *Aeschynomene elaphroxylon* (corky wood, ornamental, fodder)
- *Albizia lebbeck* (timber, ornamental, fuel), *A. procera* (timber, ornamental, tannin, poles, fuel), *A. saman* (timber, craftwood, fodder (pods), ornamental)
- *A. glutinosa* (fuel, soil stabilization, craftwood), *A. nepalensis* (furniture)
- *Baphia nitida* (dye, craftwood, medicinal, green manure)
- *Cajanus cajan* (food, fodder, green manure, fuel)
- *Calliandra calothyrsus* (fuel, green manure, honey)
- *Casuarina equisetifolia* (fuel, shelterbelt, poles, charcoal, ornamental)
- *Dalbergia sissoo* (timber, fuel)
- *Elaeagnus angustifolia* (shelterbelt, ornamental)
- *Enterolobium cyclocarpum* (ornamental, fuel)
- *Erythrina fusca* (fencerow, windbreak), *E. poeppigiana* (fencerow, ornamental, windbreak, nurse tree, green manure), *E. variegata* (ornamental, nurse tree, windbreak)
- *Faidherbia albida* (fodder, shade, green manure)
- *Flemingia macrophylla* (green manure, dye)
- *Gliricidia sepium* (fuel, nurse tree, ornamental, fodder)
- *Hardwickia binata* (timber, fodder)
- *Hippophae rhamnoides* (food (berry), medicinal)
- *Inga vera* (fuel, timber, shade, honey)
- *Leucaena diversifolia* (nurse tree, poles, fuel), *L. leucocephala* (fuel, fodder, poles, food, pulp, nurse tree, green manure)
- *Milletia pinnata* (fuel, fodder, oil, medicinal, ornamental)
- *Mimosa scabrella* (fuel, pulp, nurse tree, ornamental)
- *Paraserianthes falcataria* (timber, pulpwood, ornamental)
- *Parkia javanica* (food (pods), ornamental)
- *Pithecellobium dulce* (poles, ornamental, fodder (pods), fuel)
- *Prosopis alba* (fuel, fodder (pods), ornamental), *P. chilensis* (fuel, fodder (pods), ornamental), *P. juliflora* (fuel, charcoal, fodder (pods), honey), *P. pallida* (fuel, charcoal, fodder (pods), honey), *P. tamarugo* (fuel, fodder (pods), soil stabilization)
- *Pterocarpus angolensis* (timber, ornamental), *Pterocarpus erinaceus* (craftwood, fodder (leaves), dye, tannin), *P. indicus* (timber, ornamental)
- *Robinia pseudoacacia* (fuel, poles, ornamental, nurse tree, honey, reforestation)
- *Sesbania grandiflora* (fodder, food (flowers, pods, leaves), ornamental, nurse tree), *S. sesban* (fodder, green manure)
- *Sophora japonica* (medicinal, ornamental)
- *Tephrosia candida* (green manure, nurse tree, ornamental)
- *Tipuana tipu* (timber, ornamental)

Species	CO DE	Family	Sub Fam	Tribe
Acacia abyssinica Hochst. ex Benth.	D	Leguminosae	Mim	Acacieae
Acacia acinacea Lindl.	D	Leguminosae	Mim	Acacieae
Acacia acuminata Benth.	D	Leguminosae	Mim	Acacieae
Acacia adunca A. Cunn.	D	Leguminosae	Mim	Acacieae
Acacia alata R. Br.	D	Leguminosae	Mim	Acacieae
Acacia anceps DC.	D	Leguminosae	Mim	Acacieae
Acacia aneura F. Muell ex Benth	B	Leguminosae	Mim	Acacieae
Acacia arenaria Schinz	D	Leguminosae	Mim	Acacieae
Acacia armata R. Br. in Ait	D	Leguminosae	Mim	Acacieae
Acacia aroma Gillies ex H. & A.	D	Leguminosae	Mim	Acacieae
Acacia aspera Lindl.	D	Leguminosae	Mim	Acacieae
Acacia ataxacantha DC.	D	Leguminosae	Mim	Acacieae
Acacia aulacocarpa A. Cunn. ex Benth.	B	Leguminosae	Mim	Acacieae
Acacia auriculiformis A. Cunn. ex Benth.	A	Leguminosae	Mim	Acacieae
Acacia baileyana F. v. Mueller	C	Leguminosae	Mim	Acacieae
Acacia berlandieri Benth.	D	Leguminosae	Mim	Acacieae
Acacia berteriana Spreng.	D	Leguminosae	Mim	Acacieae
Acacia bidentata Benth.	D	Leguminosae	Mim	Acacieae
Acacia biflora R. Br.	D	Leguminosae	Mim	Acacieae
Acacia blakelyi Maid.	D	Leguminosae	Mim	Acacieae
Acacia bonariensis Gillies ex H. & A.	D	Leguminosae	Mim	Acacieae
Acacia borleae Burtt Davy	D	Leguminosae	Mim	Acacieae
Acacia brachybotrya Benth.	D	Leguminosae	Mim	Acacieae
Acacia brachystachya Benth.	D	Leguminosae	Mim	Acacieae
Acacia burkei Benth	D	Leguminosae	Mim	Acacieae
Acacia buxifolia A. Cunn.	D	Leguminosae	Mim	Acacieae
Acacia bynoeana Benth	D	Leguminosae	Mim	Acacieae
Acacia caffra (Thunb.) Willd.	D	Leguminosae	Mim	Acacieae
Acacia calamifolia Sweet	D	Leguminosae	Mim	Acacieae
Acacia cana Maid.	D	Leguminosae	Mim	Acacieae
Acacia cardiophylla A. Cunn.	D	Leguminosae	Mim	Acacieae
Acacia cavenia (Mol.) H. & A	C	Leguminosae	Mim	Acacieae
Acacia celastrifolia Benth.	D	Leguminosae	Mim	Acacieae
Acacia chariessa Milne-Redhead	D	Leguminosae	Mim	Acacieae
Acacia cognata Domin	D	Leguminosae	Mim	Acacieae
Acacia colletioides (A. Cunn.) ex Benth.	D	Leguminosae	Mim	Acacieae
Acacia complanata A. Cunn ex Benth.	D	Leguminosae	Mim	Acacieae
Acacia confusa Merr.	B	Leguminosae	Mim	Acacieae
Acacia constricta Benth.	D	Leguminosae	Mim	Acacieae
Acacia coriacea DC	C	Leguminosae	Mim	Acacieae
Acacia crassicarpa A. Cunn. ex Benth	B	Leguminosae	Mim	Acacieae
Acacia cultriformis A. Cunn	D	Leguminosae	Mim	Acacieae
Acacia cunninghamii Hook	D	Leguminosae	Mim	Acacieae
Acacia cyanophylla Lindl	D	Leguminosae	Mim	Acacieae
Acacia cyclops A. Cunn. ex G. Don	C	Leguminosae	Mim	Acacieae
Acacia davyi N.E. Br.	D	Leguminosae	Mim	Acacieae
Acacia dealbata Link	B	Leguminosae	Mim	Acacieae
Acacia deanei (R.T. Baker) Welch, Coombe et McGlynn	D	Leguminosae	Mim	Acacieae
Acacia decora Reichb.	D	Leguminosae	Mim	Acacieae
Acacia decurrens (J. Wendl.) Willd.	B	Leguminosae	Mim	Acacieae
Acacia diptera Lindl.	D	Leguminosae	Mim	Acacieae
Acacia doratoxylon A. Cunn	D	Leguminosae	Mim	Acacieae
Acacia drummondii Lindl	D	Leguminosae	Mim	Acacieae
Acacia ehrenbergiana Hayne	D	Leguminosae	Mim	Acacieae
Acacia elata A. Cunn ex Benth	D	Leguminosae	Mim	Acacieae
Acacia eremophila Fitzg.	D	Leguminosae	Mim	Acacieae
Acacia ericifolia Benth.	B	Leguminosae	Mim	Acacieae
Acacia erinacea Benth.	D	Leguminosae	Mim	Acacieae
Acacia erubescens Welw. ex Oliv.	D	Leguminosae	Mim	Acacieae
Acacia esterhazia MacKay	D	Leguminosae	Mim	Acacieae
Acacia estrophiolata F. Muell.	D	Leguminosae	Mim	Acacieae
Acacia extensa Lindl.	D	Leguminosae	Mim	Acacieae
Acacia exuvialis Verdoorn	D	Leguminosae	Mim	Acacieae
Acacia farnesiana (L.) Willd.	B	Leguminosae	Mim	Acacieae
Acacia filifolia Benth.	D	Leguminosae	Mim	Acacieae
Acacia fimbriata A. Cunn. ex G. Don	D	Leguminosae	Mim	Acacieae
Acacia fleckii Schinz	D	Leguminosae	Mim	Acacieae
Acacia flexuosa H. & B.	D	Leguminosae	Mim	Acacieae
Acacia floribunda (Vent.) Willd	D	Leguminosae	Mim	Acacieae
Acacia galpinii Burtt Davy	D	Leguminosae	Mim	Acacieae
Acacia genistoides (F. Muell.) Benth.	D	Leguminosae	Mim	Acacieae
Acacia georginae F.M. Bailey	D	Leguminosae	Mim	Acacieae
Acacia gerrardii Benth.	D	Leguminosae	Mim	Acacieae
Acacia giraffae Willd.	D	Leguminosae	Mim	Acacieae

Species	CODE	Family	Sub Fam	Tribe
Acacia gladiiformis A. Cunn.	D	Leguminosae	Min	Acacieae
Acacia glaucescens Willd.	D	Leguminosae	Min	Acacieae
Acacia glaucoptera Benth.	D	Leguminosae	Min	Acacieae
Acacia goetzei Harms	D	Leguminosae	Min	Acacieae
Acacia grandicornuta Gerstner	D	Leguminosae	Min	Acacieae
Acacia granitica Maid.	D	Leguminosae	Min	Acacieae
Acacia hakeoides A. Cunn.	D	Leguminosae	Min	Acacieae
Acacia harpophylla F. Muell. ex Benth.	B	Leguminosae	Min	Acacieae
Acacia harveyi Benth.	D	Leguminosae	Min	Acacieae
Acacia hastulata Sm.	D	Leguminosae	Min	Acacieae
Acacia hebeclada DC.	D	Leguminosae	Min	Acacieae
Acacia hereroensis Engl.	D	Leguminosae	Min	Acacieae
Acacia heterophylla Willd.	D	Leguminosae	Min	Acacieae
Acacia holosericea A. Cunn. ex G. Don	B	Leguminosae	Min	Acacieae
Acacia homalophylla A. Cunn.	D	Leguminosae	Min	Acacieae
Acacia horrida (L.) Willd.	D	Leguminosae	Min	Acacieae
Acacia horridula Meissn.	D	Leguminosae	Min	Acacieae
Acacia huegelii Benth.	D	Leguminosae	Min	Acacieae
Acacia instia Willd.	D	Leguminosae	Min	Acacieae
Acacia jonesii Muell. & Maid	D	Leguminosae	Min	Acacieae
Acacia juniperina Willd.	D	Leguminosae	Min	Acacieae
Acacia karoo Hayne	C	Leguminosae	Min	Acacieae
Acacia kauaiensis Hillebr.	D	Leguminosae	Min	Acacieae
Acacia kempeana F. Muell.	D	Leguminosae	Min	Acacieae
Acacia kirkii Oliv.	D	Leguminosae	Min	Acacieae
Acacia koa A. Gray	B	Leguminosae	Min	Acacieae
Acacia koaia Hillebr.	D	Leguminosae	Min	Acacieae
Acacia kraussiana Meissn. ex Benth.	D	Leguminosae	Min	Acacieae
Acacia latifolia Benth.	D	Leguminosae	Min	Acacieae
Acacia leptoneura Benth.	D	Leguminosae	Min	Acacieae
Acacia leucophloea (Roxb.) Willd.	C	Leguminosae	Min	Acacieae
Acacia ligulata A. Cunn.	D	Leguminosae	Min	Acacieae
Acacia linearis Sims	D	Leguminosae	Min	Acacieae
Acacia lineata A. Cunn.	D	Leguminosae	Min	Acacieae
Acacia linifolia Willd.	D	Leguminosae	Min	Acacieae
Acacia longifolia Willd.	D	Leguminosae	Min	Acacieae
Acacia luederitzii Engl.	D	Leguminosae	Min	Acacieae
Acacia lunata Sieb.	D	Leguminosae	Min	Acacieae
Acacia macrantha H. & B.	D	Leguminosae	Min	Acacieae
Acacia macrothyrsa Harms	D	Leguminosae	Min	Acacieae
Acacia mangium Willd.	A	Leguminosae	Min	Acacieae
Acacia mearnsii de Wild	A	Leguminosae	Min	Acacieae

Species	CODE	Family	Sub Fam	Tribe
Acacia melanoxylon R. Br.	B	Leguminosae	Min	Acacieae
Acacia mellei Verdoorn	D	Leguminosae	Min	Acacieae
Acacia mellifera (Vahl.) Benth.	C	Leguminosae	Min	Acacieae
Acacia microbotrya Benth.	D	Leguminosae	Min	Acacieae
Acacia mollissima Willd.	D	Leguminosae	Min	Acacieae
Acacia mooreana Fitzg.	D	Leguminosae	Min	Acacieae
Acacia myrtifolia Willd.	D	Leguminosae	Min	Acacieae
Acacia nebrownii Burtt Davy	D	Leguminosae	Min	Acacieae
Acacia neriifolia A. Cunn. ex Benth.	C	Leguminosae	Min	Acacieae
Acacia nervosa DC.	D	Leguminosae	Min	Acacieae
Acacia nigrescens Oliv.	D	Leguminosae	Min	Acacieae
Acacia nigricans R. Br.	D	Leguminosae	Min	Acacieae
Acacia nilotica (L.) Willd. ex Del.	A	Leguminosae	Min	Acacieae
Acacia nubica Benth.	C	Leguminosae	Min	Acacieae
Acacia obliqua A. Cunn. ex Benth.	D	Leguminosae	Min	Acacieae
Acacia obscura DC.	D	Leguminosae	Min	Acacieae
Acacia orfoto Schweinf.	D	Leguminosae	Min	Acacieae
Acacia oswaldii F. V. Mueller	D	Leguminosae	Min	Acacieae
Acacia oxycedrus Sieb.	D	Leguminosae	Min	Acacieae
Acacia parramattensis Tindale	D	Leguminosae	Min	Acacieae
Acacia pennata (L.) Willd.	C	Leguminosae	Min	Acacieae
Acacia pennatula Willd.	D	Leguminosae	Min	Acacieae
Acacia pentadenia Lindl	D	Leguminosae	Min	Acacieae
Acacia permixta Burtt Davy	D	Leguminosae	Min	Acacieae
Acacia podalyriaefolia A. Cunn. ex Benth.	C	Leguminosae	Min	Acacieae
Acacia polyacantha Willd.	A	Leguminosae	Min	Acacieae
Acacia provissima F. V. Mueller	D	Leguminosae	Min	Acacieae
Acacia prominens A. Cunn. ex Benth.	D	Leguminosae	Min	Acacieae
Acacia pubescens (Vent.) R. Br.	D	Leguminosae	Min	Acacieae
Acacia pulchella R. Br.	D	Leguminosae	Min	Acacieae
Acacia pumila Maid.	D	Leguminosae	Min	Acacieae
Acacia pycnantha Benth.	D	Leguminosae	Min	Acacieae
Acacia raddiana Savi.	D	Leguminosae	Min	Acacieae
Acacia reficiens Wawra	D	Leguminosae	Min	Acacieae
Acacia rehmanniana Schinz	D	Leguminosae	Min	Acacieae
Acacia restiacea Benth.	D	Leguminosae	Min	Acacieae
Acacia rhetinodes Schlechtd.	D	Leguminosae	Min	Acacieae
Acacia richii Ceroy	D	Leguminosae	Min	Acacieae
Acacia rigens A. Cunn.	D	Leguminosae	Min	Acacieae

Species	CODE	Family	Sub Fam	Tribe
Acacia robusta Burch.	D	Leguminosae	Min	Acacieae
Acacia rostellifera Benth.	D	Leguminosae	Min	Acacieae
Acacia rubida A. Cunn.	D	Leguminosae	Min	Acacieae
Acacia salicina Lindl.	B	Leguminosae	Min	Acacieae
Acacia saligna (Labill.) H. Wendl.	A	Leguminosae	Min	Acacieae
Acacia scorpoides A. Chev.	C	Leguminosae	Min	Acacieae
Acacia senegal (L.) Willd.	A	Leguminosae	Min	Acacieae
Acacia seyal Del	C	Leguminosae	Min	Acacieae
Acacia sieberiana DC	C	Leguminosae	Min	Acacieae
Acacia spadicigera Cham. & Schltr.	D	Leguminosae	Min	Acacieae
Acacia spathulata (F. Muell.) Benth.	D	Leguminosae	Min	Acacieae
Acacia spinescens Benth.	D	Leguminosae	Min	Acacieae
Acacia squamata Lindl	D	Leguminosae	Min	Acacieae
Acacia stenoptera Benth.	D	Leguminosae	Min	Acacieae
Acacia stricta Willd.	D	Leguminosae	Min	Acacieae
Acacia strigosa Link	D	Leguminosae	Min	Acacieae
Acacia stuhlmannii Taub.	D	Leguminosae	Min	Acacieae
Acacia suaveolens Willd.	D	Leguminosae	Min	Acacieae
Acacia subcaerulea Lindl.	D	Leguminosae	Min	Acacieae
Acacia sulcata R. Br.	D	Leguminosae	Min	Acacieae
Acacia swazica Burtt Davy	D	Leguminosae	Min	Acacieae
Acacia tamminensis Pritz.	D	Leguminosae	Min	Acacieae
Acacia tenuispina Verdoorn	D	Leguminosae	Min	Acacieae
Acacia tetragonocarpa Meissn.	D	Leguminosae	Min	Acacieae
Acacia tetragonophylla F. Muell.	D	Leguminosae	Min	Acacieae
Acacia tortilis (Forsk.) Hayne	A	Leguminosae	Min	Acacieae
Acacia triptera Benth.	D	Leguminosae	Min	Acacieae
Acacia tucumanensis Griseb.	D	Leguminosae	Min	Acacieae
Acacia unicifera Benth.	D	Leguminosae	Min	Acacieae
Acacia urophylla Benth.	D	Leguminosae	Min	Acacieae
Acacia verticillata Willd.	D	Leguminosae	Min	Acacieae
Acacia victoriae Benth.	C	Leguminosae	Min	Acacieae
Acacia villosa Willd.	C	Leguminosae	Min	Acacieae
Acacia visco Lorentz ex Griseb.	D	Leguminosae	Min	Acacieae
Acacia visite Griseb.	D	Leguminosae	Min	Acacieae
Acacia volubilis F. Muell.	D	Leguminosae	Min	Acacieae
Acacia welwitschii Oliv.	D	Leguminosae	Min	Acacieae
Acacia xanthophloea Benth.	B	Leguminosae	Min	Acacieae
Aeschynomene aspera L.	C	Leguminosae	Pap	Aeschynomeneae
Aeschynomene elaphroxylon (Guill. & Perr.) Taub	A	Leguminosae	Pap	Aeschynomeneae
Albizia acle (Blanco) Merr.	C	Leguminosae	Min	Ingeae
Albizia adianthifolia (Schum.) W.F. Wright	D	Leguminosae	Min	Ingeae
Albizia amara (Roxb.) Boiv	C	Leguminosae	Min	Ingeae
Albizia anthelmintica Brongn.	D	Leguminosae	Min	Ingeae
Albizia antunesiana Harms	D	Leguminosae	Min	Ingeae
Albizia brevifolia Schinz	D	Leguminosae	Min	Ingeae
Albizia carbonaria Britt.	D	Leguminosae	Min	Ingeae
Albizia chinensis (Osb.) Merr.	C	Leguminosae	Min	Ingeae
Albizia distachya (Vent.) Macb.	D	Leguminosae	Min	Ingeae
Albizia ealensis De Wild.	D	Leguminosae	Min	Ingeae
Albizia forbesii Benth.	D	Leguminosae	Min	Ingeae
Albizia glaberrima (Schum. & Thonn.) Benth.	D	Leguminosae	Min	Ingeae
Albizia gummifera (J.F. Gmel.) C.A. Smith	C	Leguminosae	Min	Ingeae
Albizia harveyi Fourn.	D	Leguminosae	Min	Ingeae
Albizia julibrissin Durazz.	B	Leguminosae	Min	Ingeae
Albizia katangensis Willd.	D	Leguminosae	Min	Ingeae
Albizia lebbeck (L.) Benth.	A	Leguminosae	Min	Ingeae
Albizia lebbekoides (DC.) Benth.	D	Leguminosae	Min	Ingeae
Albizia lophantha (Willd.) Benth.	C	Leguminosae	Min	Ingeae
Albizia odoratissima (Willd.) Benth	B	Leguminosae	Min	Ingeae
Albizia petersiana (Bolle) Oliv.	D	Leguminosae	Min	Ingeae
Albizia procera (Roxb.) Benth.	A	Leguminosae	Min	Ingeae
Albizia retusa Benth	D	Leguminosae	Min	Ingeae
Albizia saman (Jacq.) F.v.M.	A	Leguminosae	Min	Ingeae
Albizia saponaria (Lour.) Bl	D	Leguminosae	Min	Ingeae
Albizia schimperana Oliv.	D	Leguminosae	Min	Ingeae
Albizia stipulata (DC.) Boiv.	D	Leguminosae	Min	Ingeae
Albizia tanganyicensis Bak. F.	D	Leguminosae	Min	Ingeae
Albizia versicolor Welw. ex Oliv	D	Leguminosae	Min	Ingeae
Albizia zimmermannii Harms	D	Leguminosae	Min	Ingeae
Allocasuarina decussata (Benth.) L. Johnson	D	Casuarinaceae		
Allocasuarina distyla (Vent.) L. Johnson	D	Casuarinaceae		
Allocasuarina fraseriana (Miq.) L. Johnson	D	Casuarinaceae		

Species	CO DE	Family	Sub Fam	Tribe
Allocasuarina huegeliana (Miq.) L. Johnson	D	Casuarinaceae		
Allocasuarina littoralis (Salisb.) L. Johnson	D	Casuarinaceae		
Allocasuarina muellerana (Miq.) L. Johnson	D	Casuarinaceae		
Allocasuarina nana (Sieb. ex Spreng.) L. Johnson	D	Casuarinaceae		
Allocasuarina pusilla (Macklin) L. Johnson	D	Casuarinaceae		
Allocasuarina rigida (Miq.) L. Johnson	D	Casuarinaceae		
Allocasuarina torulosa (Ait.) L. Johnson	D	Casuarinaceae		
Allocasuarina verticillata (Lam.) L. Johnson	D	Casuarinaceae		
Alnus acuminata O. Kuntze	B	Betulaceae		
Alnus cordata (Lois) Desf.	D	Betulaceae		
Alnus cremastogyne Burk.	D	Betulaceae		
Alnus crispa (Ait.) Pursh	D	Betulaceae		
Alnus fauriei Lev. et Vnt.	D	Betulaceae		
Alnus ferdinandi Makio	D	Betulaceae		
Alnus firma Sieb. & Zucc	D	Betulaceae		
Alnus formosana Mak.	D	Betulaceae		
Alnus fructicosa Rupr.	D	Betulaceae		
Alnus glutinosa (L.) Gaertn.	A	Betulaceae		
Alnus hirsuta Turcz.	D	Betulaceae		
Alnus incana (L.) Moench	D	Betulaceae		
Alnus inokumai Murai & Kusaka	D	Betulaceae		
Alnus japonica Sieb. & Zucc.	D	Betulaceae		
Alnus jorullensis Humboldt, B & K	C	Betulaceae		
Alnus maritima Nutt.	D	Betulaceae		
Alnus matsumurae Callier	D	Betulaceae		
Alnus maximowiczii Callier	D	Betulaceae		
Alnus mayrii Callier	D	Betulaceae		
Alnus mollis Fern	D	Betulaceae		
Alnus multinervis Matsum.	D	Betulaceae		
Alnus nepalensis D. Don	A	Betulaceae		
Alnus nitida (Spach) Endl	D	Betulaceae		
Alnus oblongifolia Torr.	D	Betulaceae		
Alnus orientalis Decaisne	D	Betulaceae		
Alnus rhombifolia Nutt.	D	Betulaceae		
Alnus rubra Bong.	B	Betulaceae		
Alnus rugosa (Duroi) Spreng.	D	Betulaceae		
Alnus serrulata (Ait.) Willd.	D	Betulaceae		
Alnus serrulatoides Callier	D	Betulaceae		
Alnus sibirica Fisch.	D	Betulaceae		
Alnus sieboldiana Matsum.	D	Betulaceae		
Alnus sinuata (Regel) Rydb.	D	Betulaceae		
Alnus tenuifolia Nutt.	D	Betulaceae		
Alnus tinctoria V. Glabra	D	Betulaceae		
Alnus trabeculosa Handel-Mazzetbood	D	Betulaceae		
Alnus undulata Willd.	D	Betulaceae		
Alnus viridis Regel	D	Betulaceae		
Anadenanthera colubrina (Vell.) Brenan	D	Leguminosae	Mim	Mimoseae
Anadenanthera peregrina (L.) Speg	D	Leguminosae	Mim	Mimoseae
Andira fraxinifolia	D	Leguminosae	Pap	Dalbergieae
Andira frondosa	D	Leguminosae	Pap	Dalbergieae
Andira inermis (Wright) DC.	C	Leguminosae	Pap	Dalbergieae
Andira legalis	D	Leguminosae	Pap	Dalbergieae
Andira nitida	D	Leguminosae	Pap	Dalbergieae
Andira racemosa Lam. ex J. St.-Hil.	D	Leguminosae	Pap	Dalbergieae
Aphananthe philippinensis	D	Ulmaceae		
Baphia nitida Lodd	A	Leguminosae	Pap	Sophoreae
Bolusanthus spe[illegible]sus (Bolus) Harms.	D	Leguminosae	Pap	Sophoreae
Brownea ariza Benth.	D	Leguminosae	Caes	Detarieae
Brya ebenus DC.	C	Leguminosae	Pap	Desmodieae
Cajanus cajan (L.) Millsp.	A	Leguminosae	Pap	Phaseoleae
Calliandra affinis Pitt.	D	Leguminosae	Mim	Ingeae
Calliandra calothyrsus Meissn.	A	Leguminosae	Mim	Ingeae
Calliandra eriophylla Benth.	D	Leguminosae	Mim	Ingeae
Calliandra foliolosa Benth.	D	Leguminosae	Mim	Ingeae
Calliandra grandiflora Benth.	D	Leguminosae	Mim	Ingeae
Calliandra haematocephala Hassk.	D	Leguminosae	Mim	Ingeae
Calliandra haematoma Benth	D	Leguminosae	Mim	Ingeae
Calliandra inaequilatera Rusby	C	Leguminosae	Mim	Ingeae
Calliandra selloi (Spreng.) Macb.	D	Leguminosae	Mim	Ingeae
Calliandra surinamensis Benth.	D	Leguminosae	Mim	Ingeae
Calliandra tweedii Benth.	D	Leguminosae	Mim	Ingeae
Calpurnia aurea Benth.	D	Leguminosae	Pap	Sophoreae
Calpurnia floribunda Harv.	D	Leguminosae	Pap	Sophoreae
Calpurnia intrusa (R.Br.) E. Mey.	D	Leguminosae	Pap	Sophoreae

Species	CODE	Family	Sub Fam	Tribe
Calpurnia subdecandra (L'Herit.) Schweik.	D	Leguminosae	Pap	Sophoreae
Calpurnia villosa Harv.	D	Leguminosae	Pap	Sophoreae
Caragana arborescens Lam.	B	Leguminosae	Pap	Galegeae
Caragana aurantiaca Koehne	D	Leguminosae	Pap	Galegeae
Caragana frutescens Medik.	D	Leguminosae	Pap	Galegeae
Caragana pekinensis Kom.	D	Leguminosae	Pap	Galegeae
Casuarina cunninghamiana Miq.	B	Casuarinaceae		
Casuarina deplancheana Miq.	D	Casuarinaceae		
Casuarina equisetifolia Forst. & Forst.	A	Casuarinaceae		
Casuarina glauca Sieb. ex Spreng	B	Casuarinaceae		
Casuarina junghuhniana Miq.	B	Casuarinaceae		
Casuarina papuana S. Moore	D	Casuarinaceae		
Casuarina rumphiana Miq.	D	Casuarinaceae		
Casuarina sumatrana Jungh. ex de Vriese	D	Casuarinaceae		
Cathormion leptophyllum (Harms) Keay	D	Leguminosae	Mim	Ingeae
Ceanothus americanus L.	D	Rhamnaceae		
Ceanothus azureus Desf.	D	Rhamnaceae		
Ceanothus crassifolius Torr.	D	Rhamnaceae		
Ceanothus cuneatus (Hook.) Nutt.	D	Rhamnaceae		
Ceanothus impressus Trel.	D	Rhamnaceae		
Ceanothus incanus Torr. & Gray	D	Rhamnaceae		
Ceanothus integerrimus Hook. & Arn.	D	Rhamnaceae		
Ceanothus intermedius	D	Rhamnaceae		
Ceanothus leucodermis Greene	D	Rhamnaceae		
Ceanothus oliganthus Nutt.	D	Rhamnaceae		
Ceanothus sanguineus Pursh	D	Rhamnaceae		
Ceanothus sorediatus Hook. & Arn.	D	Rhamnaceae		
Ceanothus thyrsiflorus Esch.	D	Rhamnaceae		
Ceanothus velutinus Dougl.	D	Rhamnaceae		
Cedrelinga catenaeformis Ducke	D	Leguminosae	Mim	Ingeae
Celtis luzonica Warb.	D	Ulmaceae		
Celtis philippinensis Blanco	D	Ulmaceae		
Cercocarpus betuloides Nutt.	D	Rosaceae		
Cercocarpus ledifolius Nutt.	D	Rosaceae		
Cercocarpus montanus Raf	D	Rosaceae		
Cercocarpus paucidentatus Britt.	D	Rosaceae		
Chamaecrista ensiformis (Vellozo) Irwin & Barnby	D	Leguminosae	Caes	Cassieae
Chamaecrista glandulosa L.	D	Leguminosae	Caes	Cassieae
Chamaecytisus palmensis Hutch.	B	Leguminosae	Pap	Genisteae
Chordospartium stevensonii Cheesem.	D	Leguminosae	Pap	Charmichaelieae
Clathrotropis brachypetala (Tul.) Kleinh.	D	Leguminosae	Pap	Sophoreae
Clathrotropis macrocarpa Ducke	D	Leguminosae	Pap	Sophoreae
Clitoria racemosa G. Don.	C	Leguminosae	Pap	Phaseoleae
Colvillea racemosa Bojer	C	Leguminosae	Caes	Caesalpinieae
Comptonia peregrina (L.) Coult.	D	Myricaceae		
Cordeauxia edulis Hemsl.	C	Leguminosae	Caes	Caesalpinieae
Coriaria angustissima Hook. f.	D	Coriariaceae		
Coriaria arborea Lindsay	D	Coriariaceae		
Coriaria intermedia Matsum.	D	Coriariaceae		
Coriaria japonica A. Gray	D	Coriariaceae		
Coriaria kingiana Col.	D	Coriariaceae		
Coriaria lurida T. Kirk	D	Coriariaceae		
Coriaria myrtifolia L.	D	Coriariaceae		
Coriaria nepalensis Wallich	D	Coriariaceae		
Coriaria plumosa W.R.B. Oliver	D	Coriariaceae		
Coriaria pottsiana W.R.B. Oliver	D	Coriariaceae		
Coriaria pteridoides W.R.B. Oliver	D	Coriariaceae		
Coriaria ruscifolia L.	D	Coriariaceae		
Coriaria sarmentosa Forst. f.	D	Coriariaceae		
Coriaria sinica Maxim.	D	Coriariaceae		
Coriaria terminalis Hemsl.	D	Coriariaceae		
Coriaria thymifolia Humb. & Bonpl.	D	Coriariaceae		
Craibia brevicaudata (Vatke) Dunn	D	Leguminosae	Pap	Millettieae
Cyclolobium vecchii Samp.	D	Leguminosae	Pap	Millettieae
Dalbergia arbutifolia Bak.	D	Leguminosae	Pap	Dalbergieae
Dalbergia armata E. Mey.	D	Leguminosae	Pap	Dalbergieae
Dalbergia boehmii Taub.	D	Leguminosae	Pap	Dalbergieae
Dalbergia decipularis	D	Leguminosae	Pap	Dalbergieae

Species	CODE	Family	Sub Fam	Tribe
Dalbergia ferruginea Roxb.	D	Leguminosae	Pap	Dalbergieae
Dalbergia fischeri Taub.	D	Leguminosae	Pap	Dalbergieae
Dalbergia lactea Vatke	D	Leguminosae	Pap	Dalbergieae
Dalbergia latifolia Roxb.	B	Leguminosae	Pap	Dalbergieae
Dalbergia martinii F. White	D	Leguminosae	Pap	Dalbergieae
Dalbergia melanoxylon Guill. & Perr.	B	Leguminosae	Pap	Dalbergieae
Dalbergia monetaria L. f.	D	Leguminosae	Pap	Dalbergieae
Dalbergia nigra Allem.	D	Leguminosae	Pap	Dalbergieae
Dalbergia nitidula Wels. ex Bak.	D	Leguminosae	Pap	Dalbergieae
Dalbergia obovata E. Mey	D	Leguminosae	Pap	Dalbergieae
Dalbergia paniculata Roxb.	D	Leguminosae	Pap	Dalbergieae
Dalbergia sissoo Roxb.	A	Leguminosae	Pap	Dalbergieae
Dalbergia sympathetica Nimmo	D	Leguminosae	Pap	Dalbergieae
Dalbergiella nyasae Bak. f.	D	Leguminosae	Pap	Dalbergieae
Dalea pogonathera Gray	D	Leguminosae	Pap	Amorphaeae
Dalea spinosa (Gray) Rydb.	D	Leguminosae	Pap	Amorpheae
Desmodium discolor Vog	D	Leguminosae	Pap	Desmodieae
Desmodium gyroides (Roxb ex Link) DC.	C	Leguminosae	Pap	Desmodieae
Desmodium nicaraguense Oerst. (ex Benth. & Oerst.)	C	Leguminosae	Pap	Desmodieae
Desmodium oojeinensis (Roxb.) Hochr.	C	Leguminosae	Pap	Desmodieae
Dewevrea bilabiata M. Micheli	D	Leguminosae	Pap	Millettieae
Dialium zenkeri Harms	D	Leguminosae	Caes	Cassieae
Dichrostachys cinerea (L.) W. & A.	C	Leguminosae	Mim	Mimoseae
Dichrostachys glomerata (Forsk.) Chiov.	D	Leguminosae	Mim	Mimoseae
Dichrostachys spicata Domin	D	Leguminosae	Mim	Mimoseae
Dicymbe altsoni Sandw.	D	Leguminosae	Caes	Amherstieae
Dicymbe corymbosa Spruce ex Benth	D	Leguminosae	Caes	Amherstieae
Dimorphandra davisii Sprague & Sandw.	D	Leguminosae	Caes	Caesalpinieae
Dimorphandra exaltata Schott	D	Leguminosae	Caes	Caesalpinieae
Elaeagnus angustifolia L.	A	Elaeagnaceae		
Elaeagnus argentea Pursh	D	Elaeagnaceae		
Elaeagnus commutata Bernh.	D	Elaeagnaceae		
Elaeagnus edulis Sieb. ex E. Mey	D	Elaeagnaceae		
Elaeagnus longipes A. Gray	D	Elaeagnaceae		
Elaeagnus macrophylla Thunb.	D	Elaeagnaceae		
Elaeagnus multiflora Thunb.	D	Elaeagnaceae		
Elaeagnus pungens Thunb.	D	Elaeagnaceae		
Elaeagnus rhamnoides (L.) Nelson	D	Elaeagnaceae		
Elaeagnus umbellata Thunb.	D	Elaeagnaceae		
Entada abyssinica Steud. ex A. Rich.	C	Leguminosae	Mim	Mimoseae
Entada phaseoloides (L.) Merr	D	Leguminosae	Mim	Mimoseae
Entada sudanica Schweinfurth	D	Leguminosae	Mim	Mimoseae
Enterolobium cyclocarpum (Jacq.) Gris.	A	Leguminosae	Mim	Ingeae
Enterolobium schomburgkii Benth.	C	Leguminosae	Mim	Ingeae
Enterolobium timbouva Mart.	D	Leguminosae	Mim	Ingeae
Eperua falcata Aubl.	D	Leguminosae	Caes	Detarieae
Erythrina abyssinica Lam.	C	Leguminosae	Pap	Phaseoleae
Erythrina americana Miller	C	Leguminosae	Pap	Phaseoleae
Erythrina arborea Small	D	Leguminosae	Pap	Phaseoleae
Erythrina berteroana Urban	C	Leguminosae	Pap	Phaseoleae
Erythrina caffra Thunb.	C	Leguminosae	Pap	Phaseoleae
Erythrina corallodendron L.	D	Leguminosae	Pap	Phaseoleae
Erythrina crista-galli L.	C	Leguminosae	Pap	Phaseoleae
Erythrina fusca Lour.	A	Leguminosae	Pap	Phaseoleae
Erythrina glauca Willd.	D	Leguminosae	Pap	Phaseoleae
Erythrina horrida DC.	D	Leguminosae	Pap	Phaseoleae
Erythrina insignis Tod.	D	Leguminosae	Pap	Phaseoleae
Erythrina latissima E. Mey.	D	Leguminosae	Pap	Phaseoleae
Erythrina livingstoniana Bak.	D	Leguminosae	Pap	Phaseoleae
Erythrina lysistemon Hutch.	D	Leguminosae	Pap	Phaseoleae
Erythrina pallida Britt. & Rose	D	Leguminosae	Pap	Phaseoleae
Erythrina poeppigiana (Walpers) O.F. Cook	A	Leguminosae	Pap	Phaseoleae
Erythrina reticulata C. Presl	D	Leguminosae	Pap	Phaseoleae
Erythrina rubrinervia HBK	D	Leguminosae	Pap	Phaseoleae
Erythrina sandwicensis Degener	D	Leguminosae	Pap	Phaseoleae
Erythrina speciosa Andrews	D	Leguminosae	Pap	Phaseoleae
Erythrina suberosa Roxb.	D	Leguminosae	Pap	Phaseoleae
Erythrina subumbrans (Hassk.) Merr.	D	Leguminosae	Pap	Phaseoleae
Erythrina umbrosa HBK	D	Leguminosae	Pap	Phaseoleae
Erythrina variegata (L.) Merr.	A	Leguminosae	Pap	Phaseoleae
Erythrina velutina Willd.	D	Leguminosae	Pap	Phaseoleae
Erythrina zeyheri Harv.	D	Leguminosae	Pap	Phaseoleae
Erythrophleum africanum (Welw. ex Benth.) Harms	D	Leguminosae	Caes	Caesalpinieae

Species	CO DE	Family	Sub Fam	Tribe
Erythrophleum suaveolens (Guill. & Perr.) Brenan	D	Leguminosae	Caes	Caesalpinieae
Eysenhardtia texana Scheele	D	Leguminosae	Pap	Amorpheae
Faidherbia albida (Del.) A. Chev.	A	Leguminosae	Mim	Acacieae
Flemingia macrophylla (Willd.) Merr.	A	Leguminosae	Pap	Phaseoleae
Flemingia strobilifera L. Ait.	D	Leguminosae	Pap	Phaseoleae
Geoffroea decorticans (Gillies ex Hooker & Arnott) Burkart	C	Leguminosae	Pap	Dalbergieae
Gliricidia maculata HBK.	D	Leguminosae	Pap	Robinieae
Gliricidia sepium (Jacq.) Steud.	A	Leguminosae	Pap	Robinieae
Gossweilerodendron balsamiferum (Verm.) Harms	C	Leguminosae	Caes	Detarieae
Gymnostoma nodiflorum (Thunb.) L. Johnson	D	Casuarinaceae		
Hardwickia binata Roxb.	A	Leguminosae	Caes	Detarieae
Hippophae rhamnoides L.	A	Elaeagnaceae		
Hymenolobium alegoanum Ducke	D	Leguminosae	Pap	Dalbergieae
Indigofera teysmannia Miq.	C	Leguminosae	Pap	Indigofereae
Inga edulis Mart.	B	Leguminosae	Mim	Ingeae
Inga fagifolia (L.) Willd. ex. Benth.	D	Leguminosae	Mim	Ingeae
Inga heterophylla Willd.	D	Leguminosae	Mim	Ingeae
Inga ingoides Willd.	D	Leguminosae	Mim	Ingeae
Inga jinicuil Schlecht.	C	Leguminosae	Mim	Ingeae
Inga laterifolia Miq.	D	Leguminosae	Mim	Ingeae
Inga laurina (Sw.) Willd.	D	Leguminosae	Mim	Ingeae
Inga luschnathiana Benth.	D	Leguminosae	Mim	Ingeae
Inga marginata Willd.	D	Leguminosae	Mim	Ingeae
Inga oerstediana Benth.	D	Leguminosae	Mim	Ingeae
Inga pizizifera Benth.	D	Leguminosae	Mim	Ingeae
Inga thibaudiana DC	D	Leguminosae	Mim	Ingeae
Inga venosa Griseb. ex. Benth.	D	Leguminosae	Mim	Ingeae
Inga vera (L.) Willd.	A	Leguminosae	Mim	Ingeae
Laburnum alpinum (Mill.) J. Presl.	D	Leguminosae	Pap	Genisteae
Laburnum anagyroides Medik.	C	Leguminosae	Pap	Genisteae
Laburnum maritimus Bigel.	D	Leguminosae	Pap	Genisteae
Laburnum pratense L.	D	Leguminosae	Pap	Genisteae
Leucaena collinsii Britton & Rose	C	Leguminosae	Mim	Mimoseae
Leucaena diversifolia (Schlecht.) Benth.	A	Leguminosae	Mim	Mimoseae
Leucaena esculenta (Moc. & Sesse) Benth.	C	Leguminosae	Mim	Mimoseae
Leucaena greggii S. Wats.	D	Leguminosae	Mim	Mimoseae
Leucaena lanceolata S. Watson	C	Leguminosae	Mim	Mimoseae
Leucaena leucocephala (Lam.) de Wit	A	Leguminosae	Mim	Mimoseae
Leucaena macrophylla Benth.	D	Leguminosae	Mim	Mimoseae
Leucaena pallida Britton & Rose	D	Leguminosae	Mim	Mimoseae
Leucaena pulverulenta (Schlecht.) Benth.	D	Leguminosae	Mim	Mimoseae
Leucaena retusa Benth.	D	Leguminosae	Mim	Mimoseae
Leucaena salvadorensis Standley	D	Leguminosae	Mim	Mimoseae
Leucaena shannoni Donn. Smith	D	Leguminosae	Mim	Mimoseae
Leucaena trichodes (Jacq.) Benth.	D	Leguminosae	Mim	Mimoseae
Lonchocarpus capassa Rolfe	D	Leguminosae	Pap	Millettieae
Lonchocarpus domingensis (Pers.) DC	D	Leguminosae	Pap	Millettieae
Lonchocarpus latifolius (Willd.) HBK	D	Leguminosae	Pap	Millettieae
Lonchocarpus leucanthus Burk.	D	Leguminosae	Pap	Millettieae
Lonchocarpus muelhbergianus Hassler	D	Leguminosae	Pap	Millettieae
Lonchocarpus nitidus (Vog.) Benth.	D	Leguminosae	Pap	Millettieae
Lonchocarpus sericeus (Poir.) HBK	D	Leguminosae	Pap	Millettieae
Lonchocarpus violaceus (Jacq.) HBK	D	Leguminosae	Pap	Millettieae
Lysidice rhodostegia Hance	D	Leguminosae	Caes	Detarieae
Lysiloma thornberi Britt & Rose	D	Leguminosae	Mim	Ingeae
Maackia amurensis Rupr. & Maxim.	D	Leguminosae	Pap	Sophoreae
Machaerium brasiliense Vogel	D	Leguminosae	Pap	Dalbergieae
Machaerium robiaifolium (DC.) Vog.	D	Leguminosae	Pap	Dalbergieae
Maniltoa grandiflora (Gray) Scheff	D	Leguminosae	Caes	Detarieae
Medicago arborea L.	D	Leguminosae	Pap	Trifolieae
Melanoxylon brauna Schott.	D	Leguminosae	Caes	Caesalpinieae
Millettia dubia De Wild.	D	Leguminosae	Pap	Millettieae
Millettia pinnata (L.) Pierre	B	Leguminosae	Pap	Millettieae

Species	CODE	Family	Sub Fam	Tribe
Millettia stuhlmannii Taub.	D	Leguminosae	Pap	Millettieae
Millettia thonningii Bak.	D	Leguminosae	Pap	Millettieae
Millettia usaramensis Taub.	D	Leguminosae	Pap	Millettieae
Mimosa caesalpinaefolia Benth.	C	Leguminosae	Mim	Mimoseae
Mimosa scabrella Benth	A	Leguminosae	Mim	Mimoseae
Mimosa tenuiflora Benth.	D	Leguminosae	Mim	Mimoseae
Moldenhauera floribunda Schrad.	D	Leguminosae	Caes	Caesalpinieae
Mora excelsa Benth.	D	Leguminosae	Caes	Caesalpinieae
Mundulea sericea (Willd.) A. Chev.	D	Leguminosae	Pap	Millettieae
Myrica adenophora Hance	D	Myricaceae		
Myrica asplenifolia L.	D	Myricaceae		
Myrica californica Cham. & Schlebond	D	Myricaceae		
Myrica carolinensis Mill.	D	Myricaceae		
Myrica cerifera L.	D	Myricaceae		
Myrica esculenta Buch.-Ham	D	Myricaceae		
Myrica faya Ait.	D	Myricaceae		
Myrica javanica Blume	D	Myricaceae		
Myrica pensylvanica Loisel.	D	Myricaceae		
Myrica pilulifera Rendle	D	Myricaceae		
Myrica pubescens Willd.	D	Myricaceae		
Myrica rubra Sieb. & Zucc.	D	Myricaceae		
Myrica serrata Lam.	D	Myricaceae		
Myrocarpus frondosus Allem.	D	Leguminosae	Pap	Sophoreae
Myroxylon balsamum (L.) Harms.	C	Leguminosae	Pap	Sophoreae
Newtonia contorta (DC.) Burkart	D	Leguminosae	Mim	Mimoseae
Olneya tesota Gray	C	Leguminosae	Pap	Robinieae
Ormosia coarctaca Jacks.	D	Leguminosae	Pap	Sophoreae
Ormosia coccinea (Aubl.) Jacks.	D	Leguminosae	Pap	Sophoreae
Ormosia coutinhoi Ducke	D	Leguminosae	Pap	Sophoreae
Ormosia monosperma (Sw.) Urb.	D	Leguminosae	Pap	Sophoreae
Ormosia sumatrana (Miq.) Prain	D	Leguminosae	Pap	Sophoreae
Ostryocarpus gabonica (Baill.) Dunn.	D	Leguminosae	Pap	Millettieae
Ostryocarpus stuhlmannii (Taub.) Dunn.	D	Leguminosae	Pap	Millettieae
Parapiptadenia rigida (Benth.) Brenan	D	Leguminosae	Mim	Mimoseae
Paraserianthes falcataria (L.) Nielson	A	Leguminosae	Mim	Ingeae
Parasponia andersonii	D	Ulmaceae		
Parasponia parviflora	C	Ulmaceae		
Parasponia rugosa	D	Ulmaceae		
Parkia africana R. Br.	D	Leguminosae	Mim	Parkieae
Parkia biglandulosa W. & A.	D	Leguminosae	Mim	Parkieae
Parkia javanica (Lam.) Merrill	A	Leguminosae	Mim	Parkieae
Parkia roxburghii G. Don	C	Leguminosae	Mim	Parkieae
Parkia speciosa Hassk.	B	Leguminosae	Mim	Parkieae
Pentaclethra macroloba (Willd.) Ktze.	D	Leguminosae	Mim	Parkieae
Pericopsis angolensis (Bak.) van Meeuw.	B	Leguminosae	Pap	Sophoreae
Pericopsis elata (Harms) van Meeuw.	B	Leguminosae	Pap	Sophoreae
Piscidia piscipula (L.) Sarg.	D	Leguminosae	Pap	Millettieae
Pithecellobium adinocephalum Donn. Smith	D	Leguminosae	Mim	Ingeae
Pithecellobium caraboboense Harms	D	Leguminosae	Mim	Ingeae
Pithecellobium cauliflorum Mart.	D	Leguminosae	Mim	Ingeae
Pithecellobium collinum Sandw.	D	Leguminosae	Mim	Ingeae
Pithecellobium dulce (Roxb.) Benth	A	Leguminosae	Mim	Ingeae
Pithecellobium ellipticum (Bl.) Hassk.	D	Leguminosae	Mim	Ingeae
Pithecellobium lanceolatum (HKB ex. Willd.) Benth.	D	Leguminosae	Mim	Ingeae
Pithecellobium latifolium Benth.	D	Leguminosae	Mim	Ingeae
Pithecellobium montanum Benth.	D	Leguminosae	Mim	Ingeae
Pithecellobium tortum Mart.	D	Leguminosae	Mim	Ingeae
Pithecellobium trapezifolium Benth.	D	Leguminosae	Mim	Ingeae
Pithecellobium unguis-cati (L.) Benth.	D	Leguminosae	Mim	Ingeae
Plathymenia foliolosa Benth	D	Leguminosae	Mim	Mimoseae
Platymiscium pinnatum (Jacq.) Dug.	D	Leguminosae	Pap	Dalbergieae
Platymiscium stipulare Benth.	D	Leguminosae	Pap	Dalbergieae
Platymiscium trinitatis Benth.	D	Leguminosae	Pap	Dalbergieae
Poecilanthe falcata (Vell.) Ducke	D	Leguminosae	Pap	Dalbergieae
Poecilanthe parviflora Benth.	D	Leguminosae	Pap	Dalbergieae

Species	CODE	Family	Sub Fam	Tribe
Prosopis africana (Guill. & Perr.) Taub.	C	Leguminosae	Min	Mimoseae
Prosopis alba Grisebach	A	Leguminosae	Min	Mimoseae
Prosopis articulata S. Watson	D	Leguminosae	Min	Mimoseae
Prosopis chilensis Burk.	A	Leguminosae	Min	Mimoseae
Prosopis cineraria (L.) Druce	A	Leguminosae	Min	Mimoseae
Prosopis dulcis Kunth	D	Leguminosae	Min	Mimoseae
Prosopis glandulosa Torr.	D	Leguminosae	Min	Mimoseae
Prosopis juliflora (Sw.) DC.	A	Leguminosae	Min	Mimoseae
Prosopis kuntzeie Harms ex Kuntze	D	Leguminosae	Min	Mimoseae
Prosopis nigra (Griseb.) Hieron.	D	Leguminosae	Min	Mimoseae
Prosopis pallida (H. & B. ex Willd.) HBK	A	Leguminosae	Min	Mimoseae
Prosopis ruscifolia Griseb.	D	Leguminosae	Min	Mimoseae
Prosopis stephaniana (Willd.) Spreng	D	Leguminosae	Min	Mimoseae
Prosopis tamarugo Philippi	A	Leguminosae	Min	Mimoseae
Prosopis velutina Woot	D	Leguminosae	Min	Mimoseae
Pseudopiptadenia leptostachyum (Brenan ex Benth.)	D	Leguminosae	Min	Mimoseae
Psorodendron spinosum (Gray) Rydb.	D	Leguminosae	Pap	Galegeae
Pterocarpus angolensis DC.	D	Leguminosae	Pap	Dalbergieae
Pterocarpus antunesii (Taub.) Harms	D	Leguminosae	Pap	Dalbergieae
Pterocarpus brenanii (L.) Barb. & Torre.	D	Leguminosae	Pap	Dalbergieae
Pterocarpus echinatus Pers.	D	Leguminosae	Pap	Dalbergieae
Pterocarpus erinaceus Poir.	A	Leguminosae	Pap	Dalbergieae
Pterocarpus indicus Willd.	A	Leguminosae	Pap	Dalbergieae
Pterocarpus marsupium Roxb.	C	Leguminosae	Pap	Dalbergieae
Pterocarpus officinalis Jacq.	D	Leguminosae	Pap	Dalbergieae
Pterocarpus podocarpus Blake	D	Leguminosae	Pap	Dalbergieae
Pterocarpus rotundifolius (Sand.) Druce	D	Leguminosae	Pap	Dalbergieae
Pterocarpus soyauxii Taub.	C	Leguminosae	Pap	Dalbergieae
Pterocarpus vidalianus Rolfe	D	Leguminosae	Pap	Dalbergieae
Purshia tridentata (Pursh) DC	C	Rosaceae		
Robinia hispida L.	D	Leguminosae	Pap	Robinieae
Robinia pseudoacacia L.	A	Leguminosae	Pap	Robinieae
Robinia viscosa Vent.	D	Leguminosae	Pap	Robinieae
Saraca declinata Miq.	D	Leguminosae	Caes	Detarieae
Schleinitzia fosbergii Nevling & Elias	D	Leguminosae	Min	Mimoseae
Sclerolobium aureum Baillon	D	Leguminosae	Caes	Caesalpinieae
Sclerolobium micropetalum Ducke	D	Leguminosae	Caes	Caesalpinieae
Sclerolobium rugosum Martius	D	Leguminosae	Caes	Caesalpinieae
Sesbania cinerascens Welw. ex Bak.	D	Leguminosae	Pap	Robinieae
Sesbania drummondii (Rydb.) Cory	D	Leguminosae	Pap	Robinieae
Sesbania grandiflora (L.) Poir	A	Leguminosae	Pap	Robinieae
Sesbania macrantha Welw. ex Phill. & Hutch.	D	Leguminosae	Pap	Robinieae
Sesbania sesban (L.) Merr.	A	Leguminosae	Pap	Robinieae
Sesbania tomentosa Hook & A.	D	Leguminasae	Pap	Robinieae
Shepherdia argentea (Pursh) Nutt.	C	Elaeagnaceae		
Shepherdia canadensis (L.) Nutt.	C	Elaeagnaceae		
Sophora chrysophylla (Salisb.) Seem.	C	Leguminosae	Pap	Sophoreae
Sophora flavescens Ait.	D	Leguminosae	Pap	Sophoreae
Sophora japonica L.	A	Leguminosae	Pap	Sophoreae
Sophora secundiflora (Ort.) Lag. ex DC.	D	Leguminosae	Pap	Sophoreae
Sophora tetraptera J. Mill.	D	Leguminosae	Pap	Sophoreae
Sophora tomentosa L.	D	Leguminosae	Pap	Sophoreae
Sophora viciifolia Hance	D	Leguminosae	Pap	Sophoreae
Stryphnodendron adstringens Cov.	D	Leguminosae	Min	Mimoseae
Stryphnodendron barbatimam Mart.	D	Leguminosae	Min	Mimoseae
Swartzia acutifolia Vogel.	D	Leguminosae	Pap	Swartzieae
Swartzia benthamiana Miq.	D	Leguminosae	Pap	Swartzieae
Swartzia leiocalycina Benth.	D	Leguminosae	Pap	Swartzieae
Swartzia madagascariensis Desv.	D	Leguminosae	Pap	Swartzieae
Swartzia oblanceolata Sandw.	D	Leguminosae	Pap	Swartzieae
Swartzia pinnata Willd.	D	Leguminosae	Pap	Swartzieae
Swartzia simplex (Sw.) Spreng	D	Leguminosae	Pap	Swartzieae
Swartzia trinitensis Urb.	D	Leguminosae	Pap	Swartzieae

Species	CODE	Family	Sub Fam	Tribe
Sweetia praeclara Sandw	D	Leguminosae	Pap	Sophoreae
Tachigali multijuga Benth	D	Leguminosae	Caes	Caesalpinieae
Tachigali paniculata Aubl	D	Leguminosae	Caes	Caesalpinieae
Tephrosia candida (Roxb.) DC	A	Leguminosae	Pap	Millettieae
Tipuana tipu (Benth.) Kuntze	A	Leguminosae	Pap	Dalbergieae
Trema cannabina Lour.	D	Ulmaceae		
Trema orientalis (L.) Blume	C	Ulmaceae		
Virgilia capensis (L.) Poir	C	Leguminosae	Pap	Podalyrieae
Wallaceodendron celebicum Koord.	C	Leguminosae	Mim	Mimoseae
Wisteria brachybotrys S. & Z.	D	Leguminosae	Pap	Millettieae
Wisteria chinensis DC	D	Leguminosae	Pap	Millettieae
Wisteria sinensis (Sims) Sweet	D	Leguminosae	Pap	Millettieae
Wisteria venusta Rehd. & Wilson	D	Leguminosae	Pap	Millettieae
Xanthocercis zambesiaca (Bak.) Dumaz le Grand	D	Leguminosae	Pap	Sophoreae

RECENT DEVELOPMENTS IN CASUARINA RESEARCH

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FDC: 181.351: 165.3: 176.1 Casuarina Adans.

SUMMARY

In the last IUFRO Congress, the research in Casuarina in the 1975-1985 decade was summarized by the author. The past five years have witnessed a worldwide exponential increase in Casuarina research programs. This paper is intended to review recent research results with particular reference to Egypt.

Most of the research has concentrated on symbiosis and N-fixation especially after certain *Frankia* strains were isolated and their *in vitro* preparations are made available. The contribution of *Casuarina* to soil fertility gained considerable interest especially in relation to agroforestry systems and reforestation of degraded lands. The exploration of intraspecific genetic variation has progressed through provenances trials in Egypt, U.S.A., and China. Tolerance to environmental stresses has also received a lot of attention especially in relation to screening for salt tolerance and the mechanism(s) involved. Wood properties and utilization have been also under investigation.

A summary of papers presented at the Second International Casuarina Workshop held in Cairo (January 1990) will be presented along with recommendations for future research programmes.

Keywords: Casuarina, Multipurpose Trees, N-Fixing Trees, Tree Breeding

GENETICS AND BREEDING

Inter- and Intraspecific Variation In Morphological Characteristics

Variation in cone, seed and seedling morphology has been studied in several seed collections of both *C. glauca* and *C. cunninghamiana* and their natural hybrid, as the first step of breeding and improvement programmes which have been summarized by El-Lakany (1986). Inter- and intraspecific variation was recorded in material collected in Australia and in Egypt. The hybrid was found to have more affinity to *C. cunninghamiana* than to *C. glauca*, (El-Lakany and Yuness, 1985).

Provenance Trials

The first casuarina provenance trial was conducted under controlled greenhouse conditions by El-Lakany and Shepherd (1983). Tree height at the age of one year varied significantly between *C. glauca* and *C. cunninghamiana* as well as within each species, with an ecotypical pattern in the first and a clinal one in the second. Tree height varied quadratically with the latitude of seed source in *C. cunninghamiana*, but the trend in *C. glauca* was indiscernible, perhaps due to the relatively high variation within provenances.

A field trial of 9 provenances of *C. glauca*, 17 provenances of *C. cunninghamaiana* collected in Australia and 4 land races of each collected in Egypt was established in 1982 in an irrigated desert site near Cairo. At the age of two years, the average height ranged between 48 and 81 cm in *C. glauca* and between 52 and 219 cm in *C. cunninghamaiana*. Although highly interprovenance differences were evident at the age of 3 years in the field, the ranking of the provenances differed from that observed under controlled conditions. The two best provenances of *C. cunninghamiana* (from Queensland) were twice as high as the local land race. Similarly, there were up to two fold differences in height between provenances of *C. glauca*.

The same trend was more or less maintained until the age of 6 years. Tree height ranged between 3.49 and 6.55 m in *C. glauca* and between 4.17 and 10.52 m in *C. cunninghamiana*. Differences between families within provenances were much more pronounced.

In a comparable provenance trial in China, Zhi-gang, (personal communications, 1989) reported significant differences between provenances of *C. cunninghamiana*, but not between those of *C. glauca* at the age of 2.5 years. It was interesting to notice that the best performing *C. cunninghamiana* provenances in China (from Queensland) were nearly the same as in Egypt.

Provenance trials of *C. cunninghamiana* were also established at five sites in California where a total of 130 families in thirteen provenances are represented. Merwin (1990) reported significant genetic variation both between and within provenances, 12 months after planting. Most of the variability exists between families, however. The best performing provenances in California ranked very low in Egypt and did not survive in China.

The results obtained so far from greenhouse and plantation trials indicate high genetic variability both between seed sources and between families within provenances in _C_. _cunninghamiana_ and _C_. _glauca_, as well as high genotype X environment interaction, at least in _C_. _cunninghamiana_. Thus, comprehensive provenance trials are necessary before large-scale planting in new sites, and individual variability merits further exploitation as well.

SILVICULTURE

Seed Characteristics and Longevity in Storage

Variability in seed characteristics and germinability as affected by species, season of collection and position on tree crown were studied for _C_. _cunninghamiana_, _C_. _glauca_ and their natural hybrid (El-Lakany _et_ _al_. 1989). The number of seeds per cone was less in _C_. _cunninghamiana_ than in the other two taxa, and its cones collected from the upper part of the tree crown had generally the least number of seeds, followed by the middle and lower parts. Weight of 1000 seeds varied also among these taxa, with no significant differences between levels on the tree crown. Seeds collected in the spring were heavier and had more moisture content, but lower germination percent than those collected in the fall. Accordingly, it is recommended to collect Casuarina seed in the fall, although it may take longer time to germinate in the nursery. Seed should be collected from the lower portion of the tree crown of _C_. _glauca_ and from the upper portion for _C_. _cunninghamiana_.

Omran _et_ _al_. (1989) studied the effect of storage on casuarina seed germination and subsequent seedling growth. Storage at room temperature, as commonly practiced in Egypt, leads to deterioration in seed viability. Therefore, seed must be stored at 5-8°C. Interestingly enough, seedlings grown from fresh seeds grew faster than those from stored seeds in the first six months after transplanting, then the trend was reversed. Such a phenomenon deserves further investigation.

Stress Tolerance

Interest in salt tolerance of plants in general, and forest trees of economic value in particular, is growing as more saline lands are recommended for afforestation or reforestation to produce fuelwood and other timber products. Increasing amounts of saline water is being used for irrigation as well. Screening for salt tolerance is the first step in selecting species that can be grown under such conditions. The relative salt tolerance of 10 Casuarina and Allocasuarina taxa were reported by El-Lakany and Luard (1982). The most tolerant species were C. glauca, C. obesa and C. equisetifolia var. incana, while the most sensitive was A. decaisneana. The tolerant species had lower concentrations of Na$^+$ and Cl$^-$ in both shoots and roots and lower Na$^+$/K$^+$ ratios than sensitive species, (Luard and El-Lakany, 1984). These results were later on confirmed by Aswathappa and et al (1990), who further concluded that the highly tolerant species (C. equisetifolia) restricts Cl$^-$ entry into roots, reduces its transport into shoots, and localizes it in the older needles rather than in the growing tips.

A study of comparative tolerance to air and water pollution in Egypt, concluded that C. glauca could survive high levels of pollutants than C. cunninghamaiana, Eucalyptus camaldulensis and Acacia saligna, (Abd El-Halim, 1986). Casuarina accumulates more heavy metals (Fe, Cu, Pb, and Zn) in its needles, than the other two species. It was therefore recommended to plant belts of Casuarina around the potential sources of pollution, such as cement factories and iron and copper smelting plants.

Propagation

Although most Casuarina species are prolific seed producers; sexual propagation would lead to a some losses of genetic gains attained in the breeding programs. Asexual propagation is often practiced to conserve superior germplasm and for propagation of selected genotypes. Macropropagation has been achieved through air layering (Omran et al.,1983), stumps (El-Lakany and Shepherd), 1984), and stem cuttings, (El-Lakany, unpublished). On the other hand, micropropagation of several Casuarina and Allocasuarina species has been established. Abu El-Nil (1987) was able to micropropagate C. glauca, C. cunninghamiana, and C. equisetifolia both from juvenile and mature explants alike. Later on, (Barakat et al, 1989) used tissue and cell culture to micropropagate elite Casuarina trees, full sib hybrids and salt-tolerant strains as a part of a tree breeding and improvement programme. Duhoux et al. (1986) used immature female inflorescences as explants to micropropagate C. equisetifolia in order to produce homogeneous plant material required for the study of actinorhizal symbiosis.

N-fixation and Symbiosis

One of the fastest expanding fields of Casuarina research is N-fixation and microbiology of Frankia symbionat. Notably is work underway in France, U.S.A., Australia and Senegal. In Egypt, the research work on N-fixation by Casuarina began in 1976, when plantations were surveyed for the presence of nodules. Then the efficiency of N-fixation was determined under different soil types, and the contribution of Casuarina to soil fertility was assessed, (El-Lakany, 1987). The superiority of Casuarinas as pioneer species for poor and degraded soils were confirmed.

UTILIZATION

Wood Properties

The anatomical, physical, mechanical and chemical properties of Casuarina wood have been under investigation in Egypt since 1975. Samples of C. glauca wood were pulped using the Kraft process. The pulp yield is relatively high and its physical and chemical characteristics are moderate. The possibilities for upgrading the properties of Casuarina wood by producing wood/plastic composites were explored. Mathematical equations describing the changes in C. cunninghamiana wood upon exposure to gamma radiation were developed for compressive and tensile strength and for changes in extractive contents related to change in mechanical properties (El-Osta et al 1985 a,b).

Biomass and Fodder Value

Biomass production of C. glauca and C. cunninghamiana plantations in different sites at different ages was estimated. Equations were developed for such estimates based on height and dbh measurements, (Megahed and El-Lakany, 1986). For examples, mixed Casuarina irrigated plantations in a desert site yield about 180 m^3 of wood and 60 tons of green foliage per hectare at the age of 12 years. Based on the results obtained, a rotation of 12-20 years is recommended for Casuarina plantation, while Casuarina windbreaks may be renewed every 15-25 years depending upon site quality.

Casuarina foliage and suckers are grazed by cattle, sheep and goats especially if no other fodder is available. The foliage was found to contain 9.1% crude protein, 4.7% ether extracts, 36.8% crude fibre, 39.2% N-free extracts, 10.2% ash and 36.9% total digestible nutrients (Omran and Nour, 1980). Foliage has also been successfully used as an ingredient in chicken feed after drying and grinding (El-Deek _et al_, 1989).

CONCLUSIONS

Many species of the genera _Casuarina_ and _Allocasuarina_ are typical multipurpose trees. They provide shelter, fuelwood, timber, and fodder among many other uses. Casuarinas have also emerged as a prime candidate for agroforestry systems in many parts of the world. They are very versatile species, which can be grown under a wide variety of site conditions ranging from fertile to very degraded soils, from sea level to medium high elevations and from hot-dry to cold-moist climates. Several species have proven to be tolerant to high levels of soil and water salinity, and some can survive waterlogged soils as well, thus they have been recommended for planting in sites unsuitable for agriculture.

Future research will concentrate on exploring the genetic variation in some the more important species through provenance trials and testing of progenies of superior trees. Nitrogen fixation is also a rapidly expanding field of research in Casuarina. _Frankia_ inocula from efficient strains will soon be available for wide distribution around the world.

Although Casuarina wood has been known to be difficult to use in traditional industries such as furniture, reconstituted casuarina boards are being produced commercially. More research is envisaged on improving the properties and seasoning of Casuarina wood.

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EARLY HEIGHT GROWTH AND FROST TOLERANCE OF *Casuarina cunninghamiana* PROVENANCES IN FIELD TRIALS IN CALIFORNIA, USA

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FDC: 232.12: 181.221.1: 176.1 Casuarina cunninghamiana Miq.: (794)

SUMMARY

Field trials of *Casuarina cunninghamiana*, including 130 open-pollinated families from 13 provenances in New South Wales, Australia, were established in 1987 at five field sites in California, USA. Based on height growth at 24 months after planting, significant genetic variation was observed both between and within provenances. Significant differences among provenances were also observed in frost injury rating following the occurrence of mid-winter temperatures as low as -12°C.

Keywords: Casuarina, provenance trials, frost tolerance

INTRODUCTION

Casuarina cunninghamiana Miq. (river oak) is native to eastern Australia where it typically occurs in pure stands along freshwater streams and rivers. It is the largest species of the genus in Australia, attaining a height of 20-35 m and a diameter of 0.5-1.5 m (Boland et al. 1984). It has been introduced in California and widely planted elsewhere for shelterbelts, fuelwood and erosion control.

The native range of the species extends from 15-37°S latitude, within which it experiences a wide range of climatic conditions (Turnbull 1986). Analysis of allozyme loci (Moran et al. 1989) demonstrated that, compared to other plant species, *C. cunninghamiana* has a high level of genetic diversity within its native range. On the basis of early height growth, significant variation between and within provenances has been observed in greenhouse studies and field trials (El-Lakany and Shepherd 1983, El-Lakany and Yuness 1985). In California, frost hardiness is perhaps the most important factor in adaptability of introduced trees. Evidence of genetic variability within the species suggests that growth rate, cold hardiness and form could be improved by selection between and within provenances. However, to date there have been no comprehensive provenance trials or frost tolerance assessments of *C. cunninghamiana* in California.

During 1985, seed was collected from natural stands in the southern portion of the species' native range. The following year an ad hoc working group of government agencies, private industry and individual landowners formed the Casuarina Improvement Association (CIA) to pursue field testing of *Casuarina* spp. in California. Field trials were planted in 1987 at five sites in cooperation with the CIA. The objectives of these initial trials, intended to last five years, are (1) to determine the extent of genetic variation between and within provenances of *C. cunninghamiana*, (2) to measure the degree of planting site X genotype interaction, (3) to assess the relative frost hardiness of provenances, and, ultimately, (4) to identify superior families and individuals on the basis of growth, form and frost tolerance for breeding improved lines.

This paper reports on variation observed in height growth up to two years after planting, and frost injury symptoms following a severe freeze 21 months after planting.

EXPERIMENTAL METHODS

Seed Collection

Collections of seed from native stands of *C. cunninghamiana* in New South Wales, Australia, were conducted in 1985-86 through the Australian Tree Seed Centre, CSIRO Division of Forestry and Forest Products, in Canberra. The methodology and results of seed collection were reported in a previous paper (Merwin and Roffey 1987). Since the basic objective of seed collection was to obtain a representative sample of populations within the temperate (southern) portion of the native range, especially at frost-prone localities, there was no phenotypic selection of seed trees. Open-pollinated seed was collected from ten widely-separated (>100 m apart) trees within each of thirteen provenances in New South Wales, Australia (Table 1).

Table 1: *C. cunninghamiana* seedlots planted in Californian trials.

Provenance Locality	CSIRO Seedlot	Families	Lat. °S	Long. °E	Elev. m
Uriarra Crossing (UC)	14919	M1-M10	35 14	148 57	420
Wagga Wagga (WW)	14996	M11-M20	35 05	147 18	230
Cowra (CW)	14997	M21-M30	33 53	148 44	330
Bathurst (BT)	14998	M31-M40	33 21	149 38	685
Hartley (HT)	14999	M41-M50	33 33	150 09	690
Dubbo (DB)	15000	M51-M60	32 12	148 36	380
Coonabarabran (CN)	15001	M61-M70	31 17	149 11	670
Grafton (GF)	15002	M71-M80	29 50	152 53	140
Wauchope (WH)	15003	M81-M90	31 27	152 40	120
Singleton (SN)	15004	M91-M100	32 34	151 01	140
Bega (BG)	15006	M111-M120	36 37	149 50	85
Kangaroo Valley (KV)	15007	M121-M130	34 43	150 32	200
Glen Innes (GI)	15601	CG31-CG40	29 50	151 36	1010

Identity of individual tree seedlots was maintained throughout seed extraction. Average germination varied from 3010 to 13700 viable seeds per 10 g sample (Merwin and Roffey 1987).

Nursery Phase

Seed of each seedlot was germinated in a greenhouse in subdivided flats containing peat and perlite (1:1). After four weeks, seedlings were transplanted to individual plastic tube containers (164 cm^3 volume) filled with a sterilized, pH-balanced potting medium (vermiculite, perlite, peat and starter NPK nutrients). Seedlings were kept in an unheated greenhouse for two months after transplanting and fertilized weekly with a commercial 20-20-20 NPK liquid fertilizer. Thereafter, fertilizer application was stopped and the seedlings were moved outside to a shade house for hardening. Trays were rearranged periodically to minimize any edge effects.

Prior to outplanting, seedlings within each seedlot were selected on the basis of height, caliper and form (lack of forking). These were sorted into sets of trays for each planting site according to field position in order to facilitate planting. Height and caliper measurements were recorded prior to outplanting.

Seedlings were not inoculated with *Frankia* prior to planting. *Frankia* is an actinomycete bacteria that fixes atmospheric N in symbiosis with *Casuarina* spp. Strains of *Frankia* specific to casuarina are not free-living in Californian soils and none of the trial sites had prevously been planted with casuarina. Therefore, it is presumed that the trees have not become nodulated after planting.

Design and Establishment of Trial Sites

Through CIA, five planting sites were selected in northern California (Table 2). The three principal sites, Anderson, Davis and Woodland, share a common design. A total of 132 seedlots (10 families X 13 provenances plus two bulked provenance seedlots) were planted at each of the three sites in a randomized complete block design, with single tree plots and 15 replications. Nominal tree spacing is 1.8 X 1.8 m except at Woodland where trees are planted on 2.1 m centers in rows 1.5 m apart; all trees occupy an area of 3.24 m^2 each.

Two supplemental trial sites were also established, at Palermo and Oregon House. At these two sites, row plots of bulked provenances, each comprised of equal numbers of families, were planted in randomized complete blocks. At Palermo, the 13 base provenances plus two supplemental provenances were planted in 20-tree row plots with four blocks. At Oregon House, seven high-elevation provenances were planted in 10-tree row plots with four blocks. Trees at both sites are planted at 1.8 X 1.8 m spacing.

Site preparation prior to planting consisted of cultivation to remove existing weeds, and formation of beds for furrow irrigation at Palermo and Woodland. Nonselective (glyphosate) or selective preemergence (simazine)

Table 2. Climate and soils of trial planting sites

	Anderson	Davis	Woodland	Oregon House	Palermo
Latitude (N)	40 28	38 32	38 40	39 20	39 27
Longitude (W)	122 18	121 46	121 50	121 15	121 34
Elevation (m)	131	18	30	567	40
Rainfall (mm)[1]	559	440	440	1717	532
Temperatures (C)[1]	3-37	3-35	3-35	-1-26	3-36
Soil Type[2]	gravelly loam	silt loam	clay	clay loam	sandy loam
Soil pH range[2]	5.4-6.0	7.7	6.4-7.7	5.7-5.8	4.7-6.1
Planting Date (1987)	May 15	June 10	March 27	May 30	April 12

[1] Mean annual rainfall and range of minimum to maximum mean monthly temperatures from nearest recording station.
[2] Soil analysis data from Monarch Laboratory, Chico, CA.

herbicides were applied pre-planting at label rates at Anderson and Woodland. Drip irrigation systems were installed at Anderson, Davis and Oregon House. Trees were planted with shovels. A single row border of seedlings from a local seed source (CDF 5107, Davis, CA) was planted around the perimeter of all non-contiguous trial blocks. Plastic mesh tree guards supported by bamboo stakes were installed around each seedling at planting to prevent rabbit damage. All sites were irrigated immediately after planting. Dead seedlings were replaced at all sites within two months after planting.

Site Maintenance

All sites except Woodland were irrigated regularly each year from late spring through early fall. The Palermo site is irrigated with secondary wastewater effluent from a commercial fruit cannery from July through September and with well water during the spring. Trees at Woodland were irrigated twice during the first year of establishment and not subsequently. None of the three main trial sites have received fertilizer. During the two years, each tree at Oregon House also received approximately 12 g N fertilizer dissolved in the irrigation water.

Weed growth was controlled using a combination of hand cultivation and nonselective (glyphosate directed away from tree foliage) and preemergence (oryzalin or simazine) herbicides. Operational usage of selective preemergence herbicides was based on the results of tolerance screening conducted on newly planted seedlings at Davis (W.B. McHenry, U.C. Cooperative Extension, personal communication).

Grasshoppers attacked young seedlings at Anderson and were treated with malathion bait. Otherwise, insects have not caused noticeable damage. Some foliar damage from deer browsing was observed at Anderson during the first year. Sheep damaged seedlings at Woodland 10 months after planting, but the damage was confined to one area and the affected blocks have been eliminated from statistical analysis.

Growth and Frost Injury Assessment

Height growth of all trees was measured at 6, 12 and 24 months after planting with fixed or telescoping poles. Form defects, such as the incidence of forking, were also noted at each sampling interval.

In early February 1989, about 21 months after field planting, a polar air mass spread into California. Night-time temperatures fell to near record lows over the north state, including the field trial sites. At the three sites where severe frosts were experienced, frost injury symptoms were assessed at the two-year anniversary of planting date and again in July, 5.5 months after the freeze event.

A visual frost injury evaluation scale was developed, based upon a similar scale for assessing frost injury to *Eucalyptus* spp. in California (R.B. Standiford, U.C. Cooperative Extension, personal communication). The frost injury scale used for *C. cunninghamiana* is as follows: 1 - no visible damage, 2 - slight foliar damage, some with a few dead branchlets in the lower crown, 3 - moderate foliar damage, some with top dieback, 4 - moderate bark splitting, branches still alive, 5 - severe bark splitting, main branches dead but some lateral branchlets may appear alive, and 6 - tree killed to ground. No trees were rated 1 at either evaluation period.

Height, diameter and frost injury data were compiled using the statistical package MSTAT (Freed 1988). The SAS (SAS Institute 1985) procedure ANOVA was used to calculate sums of squares for a mixed, crossed and nested design. Means were separated using Fisher's protected least significant difference test.

RESULTS

Height Growth

Significant variation in height growth at two years of age was observed between blocks, provenances, families and sites (Table 3). Analysis of variance for mean height was performed for each site individually and over the three main trial sites using 10 blocks randomly selected at Anderson and Davis to balance the 10 blocks at Woodland unaffected by animal damage. No significant differences were found in either site X provenance or site X family interactions.

At 24 months after planting, the tallest mean height was 487 cm for the Singleton provenance at Palermo, compared to the lowest mean of 255 cm for the Kangaroo Valley provenance at Anderson (Table 4). It is noteworthy that the Singleton provenance was consistently tallest over all sites in which it was planted. The Bathurst provenance was second tallest at four of five sites, and was significantly different ($P<0.01$) from Singleton only at the Woodland site.

Differences in mean height growth among families at age two were also highly significant (Table 4). Figure 1 depicts the range of mean heights of

Table 3. Analysis of variance for mean height growth 24 months after planting.

	Anderson			Davis			Woodland			Oregon House			Palermo		
Source	df	ms[a]	EV[b]	df	ms	EV	df	ms	EV	df	ms	EV	df	ms	EV
Block	14	117742***	0.25	14	79158***	0.27	9	26257***	0.11	3	127204***	0.57	3	474063***	0.33
Prov.	12	11335**	0.01	12	24680***	0.06	12	11522***	0.05	6	13256**	0.08	14	38278*	0.06
P x B	168	2976ns	0.01	168	1287ns	0.00	108	1468ns	0.00	18	2829***	0.06	42	15886***	0.15
Fam(P)	117	4075***	0.03	117	3464***	0.06	117	2270***	0.04						
Error	1638	2540	0.70	1638	1402	0.62	1053	1533	0.81	252	902	0.29	1140	2130	0.46
Total Est. Variance			3636.8			2279.4			1895.5			3131.8			4624.5

Anderson, Davis and Woodland sites combined (10 blocks each)

Source	df	ms	EV
Site	2	12166589***[c]	0.79
Block (Site)	27	63024***	0.04
Provenance	12	26760***[c]	0.01
Site x Prov	24	3518ns[c]	0.00
Prov x B(S)	324	1939ns[c]	0.00
Family(Prov)	117	4646***	0.01
Site x Fam(P)	234	2105ns	0.00
Error	3159	1851	0.16
Total Est. Variance			11831.03

[a] Significance levels: ns-not significant, *-$P\leq0.05$, **-$P\leq0.01$, ***-$P\leq0.001$

[b] Proportion of total estimated variance.

[c] Tested by *quasi F* ratios (Steele and Torrie 1980).

Table 4: Mean height (cm) at 24 months; provenances ranked at each site.

Anderson		Davis		Woodland		Oregon House		Palermo	
Singleton	284.7	Singleton	479.6	Singleton	330.7	Uriarra	425.7	Singleton	486.5
Bathurst	282.6	Bathurst	472.0	Bathurst	315.2	Bathurst	367.8	Kangaroo	468.3
Dubbo	275.4	Wauchope	470.0	Wagga	309.0	Glen Innes	350.7	Bathurst	457.1
Wauchope	272.7	Dubbo	469.0	Dubbo	307.7	Coonabara.	346.6	Bega	450.7
Wagga	269.8	Wagga	467.6	Bega	307.7	Wauchope	345.8	Wagga	444.5
Bega	269.3	Coonabara.	464.1	Coonabara.	304.8	Hartley	310.0	Coonabara.	443.8
Coonabara.	268.9	Kangaroo	463.7	Uriarra	303.4			Uriarra	438.6
Glen Innes	268.9	Bega	458.4	Grafton	302.8			Cowra	437.6
Cowra	266.7	Cowra	454.8	Glen Innes	299.1			Dubbo	434.1
Uriarra	263.1	Glen Innes	453.1	Wauchope	299.0			Wauchope	432.9
Grafton	262.0	Uriarra	448.7	Cowra	296.8			Glen Innes	428.2
Hartley	257.4	Grafton	446.0	Hartley	295.6			Grafton	421.9
Kangaroo	234.9	Hartley	432.1	Kangaroo	286.1			Hartley	421.6
LSD P<0.001	19.3		17.8		17.6		35.4		53.9
Coef. Var.	18.74%		8.14%		12.86%		8.52%		13.09%
Grand Mean	268.9		459.9		304.5		352.6		441.7
Provenance									
High/Mean %	9.6		4.3		8.6		20.7		10.1
High/Low %	11.7		11.0		15.6		37.3		22.6
Family									
High/Mean %	14.1		9.1		13.6				
High/Low %	32.4		19.7		35.7				

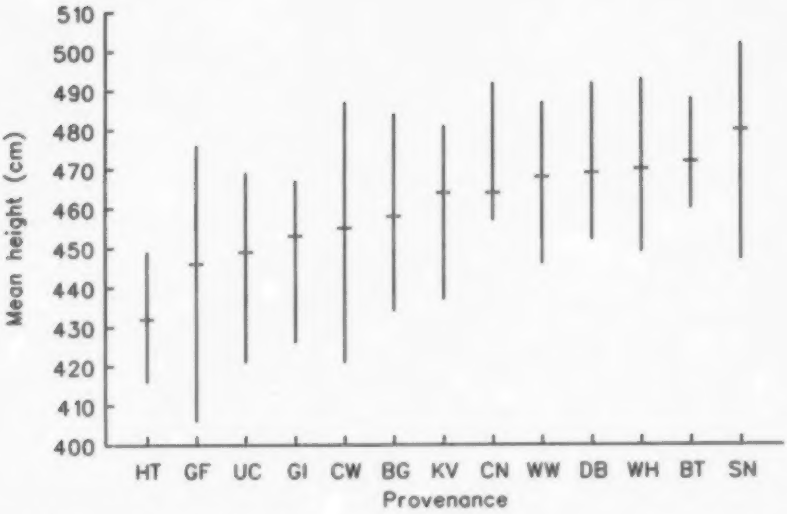

Figure 1: Range of heights of families within provenances at Davis, age 2.

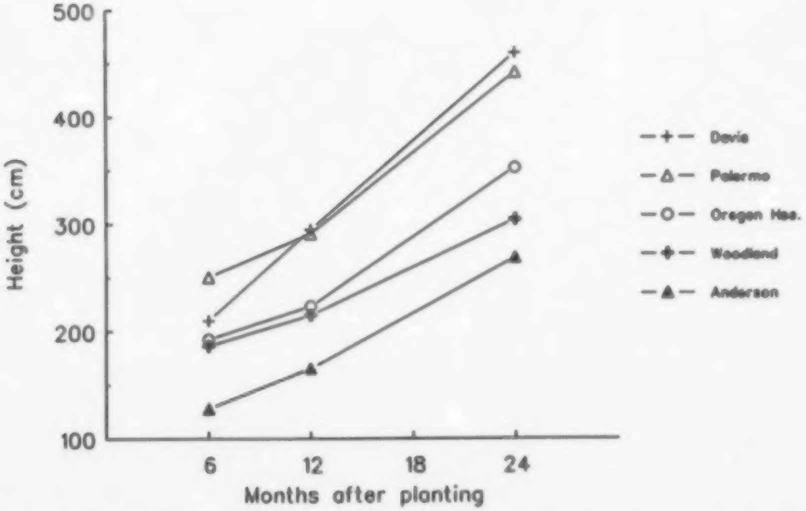

Figure 2: Grand mean height growth of provenances at all trial sites.

families within each provenance at Davis at age two. It is apparent that heights of individual families within the top eight provenances exceeded the mean height of the top-performing Singleton provenance.

Mean height growth also varied across sites (Figure 2). At 12 and 24 months after planting, the relative ranking of sites by grand mean height of all provenances remained constant. At age two, the highest grand mean at the Davis site was 460 cm, or 71 percent greater than the lowest grand mean height of 269 cm at the Anderson site.

Frost Injury

The freeze event of February 1989 severely damaged some provenances, at the Anderson, Oregon House and Palermo sites, while others survived relatively unscathed (Table 5). Minimum temperatures at Davis and Woodland remained above -8° C and no visible injury symptoms were apparent on any provenance.

Table 5: Frost injury rating of provenances at three trial sites.

Anderson		Oregon House		Palermo	
Hartley	2.01 (10)[1]	Hartley	2.60	Hartley	2.00
Bathurst	2.01 (10)	Bathurst	3.24	Bathurst	2.00
Uriarra	2.01 (10)	Uriarra	3.64	Bega	2.01
Glen Innes	2.02 (10)	Glen Innes	4.04	Glen Innes	2.04
Wagga	2.03 (10)	Davis, CA	4.69	Uriarra	2.06
Cowra	2.05 (9)	Coonabarabran	4.94	Cowra	2.26
Bega	2.08 (8)	Wauchope	5.56	Wagga	2.29
Dubbo	2.18 (7)			Coonabarabran	2.43
Coonabarabran	2.27 (3)			Dubbo	2.57
Kangaroo	2.28 (5)			Kangaroo	2.58
Singleton	2.36 (1)			Singleton	3.32
Wauchope	2.87 (0)			Wauchope	3.77
Grafton	3.80 (0)			Grafton	4.08
LSD P<0.01	0.16		0.56		0.26
Coef. Var. %	23.21		23.54		24.10
Min. temp.(C)[2]	-10.6		-12.8		-11.1

[1] Number of families in ten with mean frost injury rating ≤2.20.
[2] Minimum temperature recorded at trial site during Feb. 1989 freeze event.

The severity of injury observed five months following the freeze was greatest at Oregon House which experienced the lowest minimum temperature and below-freezing temperatures for seven days. Heavy wet snow bent down many of the trees there, although no top breakage occurred. Only the Hartley provenance survived with relatively little damage.

Minimum temperatures at Anderson and Palermo were roughly equivalent, and the duration of freezing temperatures and amount of snowfall was less at both sites compared to Oregon House. The same group of provenances (Hartley, Bathurst, Uriarra Crossing, Glen Innes, Wagga Wagga, Cowra and Bega) appeared relatively frost hardy at both sites, i.e. had frost injury ratings ≤ 2.16 at Anderson and ≤ 2.26 at Palermo (Table 5). The number of families at Anderson with mean frost injury ratings ≤ 2.20 generally follows the relative ranking of provenances by frost injury. Nevertheless, variation in frost hardiness is apparent among families within some provenances, e.g. Dubbo, Coonabarabran and Kangaroo Valley.

Some improvement in injury symptoms of trees was observed between the first and second evaluations (partial healing of bark splits), but the relative ranking of provenances did not change.

CONCLUSIONS

The results of Californian field trials to date may be indicative of the early performance of *C. cunninghamiana* provenances in managed plantations in Mediterranean environments. The ranking of provenances by mean height appears relatively consistent. Variation due to provenance effects is nearly eight times larger than the provenance X site interaction effect.

Differences in the grand mean heights of provenances observed across sites are likely due to environmental and cultural factors. In general, expression of genetic variation in height growth was lower under difficult site conditions. Lower growth at Woodland is a reflection of the lack of irrigation after establishment, severe weed infestation and heavy clay subsoil which may impede percolation and aeration. (Northern California experienced below-normal rainfall during the period 1985-1987). Poor growth at Anderson may be due in part to problems during the establishment phase, such as herbicide injury and vandalism to the irrigation system. At Palermo, trees are planted in long narrow blocks only five rows wide (three trial trees plus two buffer rows). Greater edge proximity and frequent summer irrigation with nutrient-rich wastewater may account for the rapid growth there. Soil analysis prior to planting revealed a high level of NO_3 (84 ppm) in the surface soil at the Palermo site. The Davis planting site, on prime agricultural soil, received consistent irrigation and weed control, reflected in the low coefficient of variability there (Table 4).

Allozyme studies of native populations in Australia indicate that genetic differentiation within single drainages is low, and maximum diversity is found between populations from different watersheds widely separated by latitude (Moore and Moran 1989, Moran et al. 1989). Families within each of the populations studied (Moran et al. 1989) accounted for the major proportion (75.4%) of the genetic variation. In the Californian trials, highly significant variation was found at both the provenance and family levels. Again, the overall level of variation among families was greater than between provenances, and several provenances contained families that exceeded the tallest provenance mean height at age two.

Moran et al. (1989) also found a latitudinal cline in genetic diversity, reflected in a high correlation between observed heterozygosity and the height at one year of seedllings growing in a field trial in Egypt (El-Lakany and

Yuness 1985). Results of the Californian trials to date show no correlation between provenance mean height and the latitude, longitude or elevation of the provenance locality. However, a significant correlation was found between mean frost injury rating and provenance locality ($r=0.99$, $P\leq 0.01$). Optimal locations for the selection of provenances for California plantings in terms of both height growth and frost tolerance were estimated to be near about 32°S latitude and 149°W longitude, in southern New South Wales.

Table 6: Top ten families ranked by height (cm) at age 2 years.

Davis			Means over three sites[1]		
Top 10 Families	Mean Height	Tree Height Range	Top 10 Families	Mean Height	Frost[2] Injury Rating
M93 (SN)	501.7	415-570	M93 (SN)	376.8	2.0
M97 (SN)	493.7	445-545	M32 (BT)	375.5	2.0
M89 (WH)	493.0	420-540	M24 (CW)	368.8	2.0
M51 (DB)	492.3	435-580	M15 (WW)	366.5	2.0
M68 (CN)	492.0	430-585	M58 (DB)	364.7	2.1
M58 (DB)	491.3	420-550	M33 (BT)	364.5	2.0
M33 (BT)	488.0	440-530	M97 (SN)	363.8	2.2
M99 (SN)	487.7	420-540	M112 (BG)	363.7	2.0
M32 (BT)	487.3	425-555	M31 (BT)	363.5	2.0
M87 (WH)	487.3	430-560	M113 (BG)	362.3	2.1

[1] Means over Anderson, Davis and Woodland sites.
[2] Mean frost injury rating at Anderson.

For California environments subject to periodic frosts, selection within provenances of families showing both good growth and frost hardiness will be desirable. Table 6 ranks the top ten families by two year height at Davis versus those families combining top height growth over three sites with frost hardiness. The Singleton and Bathurst provenances account for five of the top ten families whether ranked by height alone or height plus frost tolerance. Proportional representation of other provenances depends on whether frost tolerance is considered.

A total realized height gain over the three main sites of about six percent would be achieved by thinning the stands to the tallest two provenances and the best single families within each. Estimated gain for family selection (10.47 cm) is slightly higher than for provenance selection (10.35 cm). This suggests that selection to maximize growth and frost tolerance should be carried out at the level of provenances and families within selected provenances. Selection on the basis of growth, frost tolerance and form will be done at the conclusion of initial field testing in year five.

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NITROGEN FIXING WOODY LEGUMES

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FDC: 181.351: 176.1

SUMMARY

Not all legumes can nodulate. A summary of those woody genera that are known to nodulate is given, based on a taxonomic framework. Where there is doubt or lack of information, suggestions are made as to which genera merit most urgent attention.

Even if a woody legume has the genetic capacity to nodulate, it may not do so under field conditions. Climatic, edaphic and microbiological constraints to nodulation are outlined.

The problems of measuring nitrogen fixation by woody legumes in the field are briefly discussed. The extent to which fixation may occur in different environments is tentatively indicated.

Keywords: Woody legumes, nodulation, nitrogen fixation, rhizobia.

INTRODUCTION

There is an increasing interest in the use of nitrogen fixing trees, both legume and non-legume, for all the purposes for which trees generally are used, but with the additional benefit of potential soil improvement. In the last decade there has been an explosion of publications on the subject, usually with the problems of a particular geographical area in mind. Excellent protocols are being developed for propagating, growing and harvesting nitrogen fixing trees in various parts of the world.

However, apart from a few widely grown genera such as *Acacia*, *Gliricidia* and *Leucaena*, there is a paucity of substantiated information on which legumes CAN nodulate, which DO nodulate, and WHERE and WHEN they do so. This paper concentrates on these general aspects of nitrogen fixing woody legumes. The only practical problems which will be addressed are how to find and recognise nodules and how to measure nitrogen fixation in the field. Our overall goal is to improve the foundation upon which practical field work can be based. Literature citations have of necessity been very selective, but should act as an introduction to the subject.

WHICH LEGUMES CAN NODULATE?

The taxonomy used here follows that in the volume edited by Polhill and Raven (1981) with recent modifications as incorporated and referenced in Faria *et al* (1989). Nodulation data are from the latter publication, which updates the classic volume of Allen and Allen (1981). In these publications the Leguminosae is divided into three sub-families, the Caesalpinioideae, Mimosoideae and Papilioniodeae. Current opinion favours the evolution of extant legumes from a tropical caesalpinioid ancestor, almost certainly woody. Familiar herbaceous crop legumes, such as soybean and clovers, are considered to be advanced.

Most of the extant caesalpinioid and mimosoid legumes are woody as are some of the more basal tribes of the Papilionoideae. Less than half of the genera have been examined for nodules. When nodules are found they often differ greatly in morphology and anatomy from those on crop species.

These facts (together with the difficulty of identifying some of the plants) have tended to confuse the picture of nodulation in woody legumes. Some produce nodule-like structures which are not nodules (i.e. do not contain rhizobia and do not show nitrogenase activity) (Sprent, 1986). Others produce nodules which are large, (5–7 cm), and may be black and woody, so not readily recognised as nodules (Faria, McInroy and Sprent, 1987). Thus it is easy to have both false positive and false negative reports. Other features which can often be diagnostic in herbaceous legume nodules, such as pink internal colour, indicating the presence of haemoglobin can be found in outgrowths on roots of trees induced and inhabited by nematodes. The classic microbiological procedure of establishing Koch's postulates (isolation of rhizobia, re-inoculation to produce nodules and re-isolation) is not always easy because rhizobia in some nodules are retained inside persistent infection threads (Faria *et al*, 1987) from which they are difficult to isolate. Further, rhizobia from some trees grow much more slowly than even the so-called slow growing crop legume rhizobia. These facts, which have only emerged in the last five years or so, help to explain many of the conflicting reports on nodulation found in the literature.

For these reasons, when considering nodulation in the Caesalpinioideae where the situation is most confused, it is at present safest to assume potential nodulation in only those genera for which there are properly confirmed reports, usually backed up by studies of nodule structure and tests for nitrogenase activity. This approach excludes many of the genera for which positive reports are cited by Faria *et al* (1989) and reduce the list to 8. Seven of these, *Campsiandra*, *Dimorphandra*, *Erythrophleum*, *Melanoxylon*. *Moldenhawrea*, *Sclerolobium* and *Tachigali* are from 3 of the 8 groups into which the tribe Caesalpinieae has been divided (Polhill and Raven, 1981). Other genera within these groups have either no reports, negative reports or (rarely) unconfirmed positive reports. Genera for which there are consistent negative reports such as *Schizolobium*, *Peltophorum* and *Delonix* probably cannot nodulate, but those for which there are no reports or unconfirmed positive reports should be targeted for examination. These include the important drought resistant genus *Cordeauxia*. Unfortunately an apparent typographical error in Halliday and Nakao (1982) led to the false impression that *Parkinsonia* nodulates: there is no published evidence for this and much against (e.g. Allen and Allen, 1981). We have grown it with many different rhizobia, all with no effect. *Parkinsonia* is one of those genera that often produces nodule-like structures in the axils of roots (Sprent, 1986).

The eighth well-established genus of nodulating caesalpiniod plants is *Chamaecrista*. This makes it unique amongst the 20 genera of the tribe Cassieae. Recent taxonomic changes lead to some confusion here. The former large genus *Cassia* is being divided into three, *Cassia*, *Chamaecrista* and *Senna*. The process of division, described by Irwin and Barneby (1981) is complete for North American (Irwin and Barneby, 1982) and African (Lock, 1988) species. There are no confirmed reports of nodulation in any species of the revised genus *Cassia* (which includes some very important trees such as *C. siamea*) or in *Senna*. The large genus *Bauhinia* has only one unconfirmed report of nodules, 38 published negative reports and numerous unpublished negative observations. Both *Cassia sensu stricto* and *Bauhinia* have species which do very well in poor soils. It would be interesting to know why, but we should not be led into thinking it is because they produce nitrogen fixing root nodules. Similarly, we are at present sceptical about the single positive report of *Tamarindus* nodulating: this has been widely examined by others, with no nodules being found, but it is one of those genera which produce pink nematode galls on roots. For discussion of other caesalpinioid genera, see Faria *et al* (1989) and references therein.

In the sub-family Mimosoideae, nodulation is fairly general, but with some noteworthy exceptions. These include a few species of *Acacia* (e.g. *A. glomerosa*, *A. greggii*), which may have lost the ability to nodulate (Sprent, 1990). Within the tribe Mimoseae, four groups appear not to nodulate (Faria *et al*, 1989), including the large Amazonian tree *Dinizia excelsa*. The genus *Parkia*, from the reports available, appears to nodulate in some countries, but not in others. Its species are of considerable local importance for a wide range of purposes (Allen and Allen, 1981) and its potential for nodulation urgently needs to be checked.

Like the Mimosoideae, most woody members of the Papilionoideae nodulate, but again with some exceptions. Of the 12 genera in the tribe Swartzieae (formerly included in the Caesalpinioideae), only *Swartzia* is known to nodulate, but 6 have not been examined. Included amongst those which appear not to nodulate is the important Central American and Brazilian genus *Zollernia*. Two of the 3 Central and South American tree genera comprising the tribe Dipterygeae (*Dipteryx*, *Pterodon*) appear not to nodulate: there is no information for *Taralea*. Within the large, rather heterogeneous tribe Sophoreae there are many important trees. The nodulation status of some, such as *Myrocarpus* is open to question. Because of the potential use of many genera in this tribe and because of its intrinsic interest for the evolution and taxonomy of legume nodulation (Sprent, Sutherland and Faria, 1989), selected genera should be on the list for urgent attention.

The papilionoid tribe Dalbergieae contains a number of the world's most important tree genera. One, *Pterocarpus*, appears to nodulate in Africa, Asia and Venezuela but not in Brazil. Several small genera of local importance, including the monotypic *Inocarpus edulis* may not nodulate. Otherwise nodulation is rather general, although the size and shape of nodules varies considerably.

WHAT AFFECTS NODULATION IN THE FIELD?

Over the last century this subject has been extensively and intensively studied for crop species. Factors affecting growth and survival of both host plant and rhizobia are involved (see Sprent and Sprent, 1990, and references therein, also the volume edited by Stacey, Evans and Burris (1990)). Some of the factors such as soil pH, water supply, mineral nutrition and temperature will also apply to tree species, but not necessarily to the same extent or in the same fashion. To take a single example, we consider the growth of roots in a way that allows them to be infected by rhizobia. The most widely studied process of infection occurs through root hairs. Root hair growth can be affected by many biotic and abiotic factors in soil (Sprent and Faria, 1988; Sprent 1989): these in turn can affect nodulation. In woody plants with a root hair infection process (e.g. *Prosopis, Sesbania*) similar constraints may obtain. However, in a few crop plants (e.g. *Arachis, Stylosanthes*) and and a number of woody genera (e.g. *Dalbergia, Machaerium*) nodules are associated with lateral roots. In the crop genera, infection has been established as occurring *via* wounds where lateral roots emerge. For reasons discussed elsewhere (Sprent, Sutherland and Faria, 1987) we think this is also likely in the woody genera. We have no idea what soil factors affect infection in these plants. Because some legumes lack both root hairs and association of nodules with lateral roots (Sprent *et al*, 1989) we looked for direct infection through an intact root epidermis. This has now been established for the important fast-growing woody species *Mimosa scabrella* (Faria, Hay and Sprent, 1988). Again, environmental factors which might affect such an infection process are unknown. The mode of infection, like nodule structure, is largely host controlled. The same rhizobial strain may effect entry into different hosts by different routes. Additionally, a single rhizobial strain may be able to infect plants from different sub-families. Host specificity varies widely (Young and Johnston, 1989).

However, the rhizobial component is also a vital part of the establishment of effective nodules in the field. We now know that rhizobia should be divided into at least 3, possibly 5 (so far) genera (Sprent, 1989, 1990, Young 1990). The first two, *Rhizobium* and *Bradyrhizobium* arise from studies with crop plants. The other 1−3 (*Azorhizobium, Sinorhizobium, Photorhizobium*) arise from studies with a wider range of hosts (*Sesbania*, Chinese soybeans and *Aeschynomene* respectively). Since few of the rhizobia from woody plants have been studied in sufficient detail, further new genera may be found. Factors affecting their growth and survival in soil under natural conditions largely remain to be studied, although work has begun, for example on drought tolerance of rhizobia infecting *Prosopis* (Shoushtari and Pepper, 1985). Distinct populations, even different genera of rhizobia, may be found near the surface or deeper down in soils supporting legume trees (Walden *et al*, 1989).

The whole process of isolating and characterizing rhizobia from woody plants is a daunting task but one which a number of laboratories throughout the world are now tackling. Even more daunting is the testing of rhizobia against host provenances for effectivity, but again work is in progress. A more coordinated international effort, including field trials, is warranted. NifTAL have carried out valuable work in this area and also published an excellent practical handbook (Somasegaran and Hoben, 1985).

HOW DO WE CHECK FOR NODULES?

This can be extremely difficult and time consuming with woody plants. In many instances nursery sites are a good place to begin, examining young plants. In humid areas, young seedlings as found, for example, in forest clearings or roadsides should be carefully dug up and examined. In drier areas young plants may not be the best subjects, because their most immediate need is a good tap root to reach soil moisture. Investment of seed nitrogen in nodules may be a luxury they cannot afford until they have solved their water harvesting problems (Sprent and Raven, 1985). This may take several years, although the plants of the same species in a greenhouse may nodulate in a few weeks. In such cases scraping soil from near the trunks of established trees, and following surface roots when soil is moist can result in success. In some really dry areas all nodules may be metres down, near the water table and virtually inaccessible (Jenkins, Virginia and Jarrell, 1988). A completely different approach is to grow seeds in pots and inoculate them with a cocktail of rhizobia from species as closely related as possible. Before a species can really be considered not to nodulate, as many different types of observation as possible should be made.

If outgrowths on legume roots are found in the field the next problem is to decide whether or not they are nodules. If possible, a nitrogenease assay, using the acetylene reduction method should be carried out as soon as possible, using roots without outgrowths as a control (Bergersen, 1980). Some 'nodules' should be placed in small vials over a desiccant such as silica gel for transport to a suitable laboratory. There they can be rehydrated, rhizobia isolated and simple structural studies carried out. An experienced person can often tell from a hand section viewed under a modest light microscope. whether an outgrowth is a nodule. Morphological characters as studied extensively by Corby (1981, 1988) and also given in Allen and Allen (1981) supplemented by photographs published by Faria *et al* (1984, 1987) should also be checked. Reinfection of host seedlings by isolates from supposed nodules is obviously desirable, but not always as easy as it may appear. It may be difficult, or even impossible, to obtain nodulation under conditions which are sterile apart from the host seed and the inoculant. There is evidence that, as has been well documented for the non-legume *Alnus* with *Frankia* (Knowlton, Berry and Torrey, 1980), soil bacteria other than the nitrogen fixing species may 'help' in the setting up of nodules (possibly by making the root/root hair surface suitable for infection).

CAN WE MEASURE FIXATION BY WOODY PLANTS IN THE FIELD?

The simple answer to this question is 'not easily'. The acetylene reduction assay (Bergersen, 1980) is a useful test for active nodules, if you can find them, but is not at the moment quantitative in the field. It is never likely to be quantitative for woody plants of any size because of the volume occupied by the nodulated root system.

Assays for specific products of nitrogen fixation. such as ureides in the case of soybean have so far proved unreliable (e.g. Kessel, Roskoski and Keane, 1988) and in any case would be of very restricted application. Methods involving soils enriched with the stable isotope ^{15}N (Bergersen, 1980) are unsuitable for reasons of cost and practicability, except possibly on small nursery plants. We are currently investigating the use of natural abundance levels of ^{15}N (Shearer and Kohl, 1986), but anticipate that its usefulness could be restricted to certain sites where variability of ^{15}N in soil is not too great. Measurements such as sustained yield and yield differences between nitrogen fixing and non-fixing plants have been made, but they also present practical problems.

However, in spite of all these difficulties, there have been noble attempts to quantify nitrogen fixation by woody legumes in the field using each of the above methods. Values obtained range from up to 500 kg N ha^{-1} a^{-1} for *Leucaena leucocephala* (Vergara, 1982) to less than 1 kg N ha^{-1} a^{-1} for some species of *Acacia* (e.g. Lawrie, 1981). Other species of *Acacia* may fix around 200 kg N ha^{-1} a^{-1} (e.g. Fredrick *et al*, 1985). The upper values are similar to those for good herbaceous crop legumes. The lower ones have generally been obtained for poor, dry soils. Any nitrogen fixed is clearly an advantage, but does not necessarily lead to a soil enriched with combined nitrogen. Two factors have to be taken into account. First, most legumes are very good scavengers of soil nitrogen. Given the opportunity, they will generally use this in preference to fixing atmospheric nitrogen. Second, the amount of nitrogen removed as fuel wood, pods, foliage for animal feed or other purposes must be set against the amount fixed. If more nitrogen is removed than fixed, legumes will deplete rather than enrich soil nitrogen. However, they will do this less than non-fixing plants.

Another source of nitrogen loss is fire. Woody legumes frequently regenerate after fire, but do not necessarily replace the nitrogen lost (Lawrie, 1986). A further factor which should be considered in relation to total nitrogen fixed is the needs of the plant. Slow-growing woody plants, adapted to dry, poor nutrient soils will need less nitrogen than fast-growing plants such as *Gliricidia* grown in humid conditions. Thus a low level of nitrogen fixation may be plenty in areas where there are other constraints on plant growth. These other constraints need to be taken into account if the full potential of nodulating woody legumes is to be realized. A multidisciplinary, site-specific approach is most likely to achieve this realization.

CONCLUDING COMMENTS

We believe that nitrogen-fixing woody legumes have an important role to play in modern forestry. Unfortunately too many assumptions have been made in the past about the extent to which woody legumes can and do fix nitrogen. If they are to be managed properly, research goals need to be clearly identified. In addition to extensions of work in progress on inoculant production and field trials we recommend that:

1. The data-base listing nodulation amongst woody legumes be extended, initially by targetting certain genera.
2. Basic studies on nodule physiology are essential if constraints on nitrogen fixation in the field are to be understood. We are a century behind crop physiologists and have a new set of rules to write!
3. Serious consideration should be given to setting up a type collection of nodules, in the way that herbaria and culture collections serve as references for their component organisms.

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FOREST DECLINE, NUTRITIONAL DISTURBANCES AND AIR POLLUTION IN SOUTHERN CHINA

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In 1984, the Chinese Academy of Forestry initiated a multidisipline preliminary study on the decline and death of 6000 ha. Armand Pine in Wushan Mountain, Sichuan Province in the Southwestern China, and in February 1985, the first study report in China on air pollution and forest decline was published. Since then, the study and discussion on the cause of forest decline in China have been extending to the effect of air pollution on forest, rather than the merely looking into the cause of disease and insect pest in the past.

The preliminary investigation in the area shows that the needle chlorosis (yellowing) of Armand Pine is a common symptom of forest decline in the mountaineous region, and a significant increase of the symptom has been seen for the past decade. The SO2 and rain pH data were collected from 3 monitoring sites in the area. The soil and needle analysis were carried out. The preliminary results indicate that yellowing was evident on all sites of lower soil pH, and about soil nutrient status Mg deficiencies were most notable on acid soils with percent base saturations at 3.2-7.5%. Mg, K, Zn, (particularly Mg) contents of current needle were all deficient. Exchangeable Mg in soil of heavily damaged forest stand was lower than that of well-growing forest. But the degree of yellowing does not rise along with the increase of Al concentration. The preliminary investigation in the southwest indicates that the forest damage is associated with nutritional disturbances, and the existence of magnesium deficiency is report as the most predominant agent in causing symptoms of yellowing foliage.

Since the investigation and study are just in the beginning stage, lacking long-term quantative observation and measurement in fixed sites, much research is required to clarify the causality. The reliability of many conclusions yet needs still more evidences to prove, and the conclusion of possible causes are still in the stage of hypothesis and speculation.

SOME PROBLEMS WITH THE INTERPRETATION OF INTERNATIONAL ASSESSMENTS OF FOREST DAMAGE

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SUMMARY

The relationship between air pollution and forest damage was one of the most active research areas within forestry during the 1980s. The research was stimulated by reports of a widespread and severe decline in forest health. While initial reports were largely anecdotal, later assessments were based on data provided by national and international surveys of forest condition. These data have mostly been accepted without any rigorous examination of their reliability. There is now evidence that many problems exist with the collection, analysis and interpretation of such data. It is clear that the data do not provide evidence of damage to forests by air pollution. Instead, they provide rather limited evidence of the sum of all the factors that affect forest condition. The surveys have failed to identify any consistent relationship between air pollution and forest condition, throwing into question the widely held view that air pollution is the most important factor determining the health of forests.

Keywords: Forest health, air pollution, crown density, crown discoloration.

INTRODUCTION

In 1987, a manual for the assessment of forest damage was completed by the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests under the auspices of the Convention on Long-Range Transboundary Air Pollution of the United Nations Economic Commission for Europe (UN-ECE). In the same year, the European Economic Community (EC) introduced legislation making it compulsory for Member States to assess forest damage using the detailed criteria established by the UN-ECE. Many countries had already started programmes of their own prior to 1987 and some of these surveys were of a non-standard nature. Consequently, full harmonization of the programme throughout Europe has been slow. The results of the surveys have been widely used by the media, politicians, scientists and others, although interpretations have varied and frequently the various caveats written into national or international reports have been ignored.

In this paper, the limitations of the surveys are examined from the point of view of the scientific interpretation of the results. The emphasis that has been placed on the results is not always justified and extreme caution should be exercised when examining the data.

SAMPLING

The most fundamental aspect of any survey is the sampling design. When the annual surveys conducted in the Federal Republic of Germany were established, a systematic sampling design, based on a 4 x 4 km grid was considered to provide the most representative results. However, it was clear that many countries would be unable to sample at such an intensity and a compromise figure of 16 x 16 km was adopted. At the time, no attempt was made to determine whether this was the most appropriate sampling interval, despite the presence of data from several countries that would have enabled the efficiencies of different sampling intervals to be tested. It was assumed that the same sampling design and density could be applied throughout Europe, despite the major differences in the nature, extent and distribution of forests within individual countries. For example, 40% of the land area of Portugal is forested whereas the figure for Ireland is only 5%. Britain has 10% of its land area covered in forest and the distribution is non-uniform. Most of the forestry is in Wales and Scotland and the industrial areas of central England contain few forests. The use of a systematic sampling design means that the sampling density is proportional to the forested area, with the effect that regions where pollution-related problems could occur have virtually no sample plots.

A number of alternative sampling designs exist Innes (1988a). Essentially, stratified random sampling designs provide a more efficient means of sampling where the distribution of forests is non-uniform. However, the use of such a design has been avoided by most countries. An alternative is to increase the sampling density of a systematic design in specific target areas. Both of the above assume that some degree of knowledge is available on the distribution of the object being sampled. This is the case now but several countries had little knowledge of the nature of their forests at the start of the programme.

At each sample site, the recommended practice is to assess 24 trees. These can be selected in a number of different ways, although the most favoured design is a cross-cluster, with six trees in each cluster. This is not always possible and, in practice, other objective techniques have been used. There is no restriction on species and any tree taller than 40 cm is normally included. In countries with a variety of different forest species, sample sizes can therefore be small. This is illustrated by reference to the data for Britain (Table 1). When sample sizes are broken down by age, as is normally the case, the samples are even smaller.

Table 1: Numbers of trees sampled in the British portion of the UN-ECE and EC surveys of forest health.

Species	<60 years old	>60 years old	Mixed Age Stands	Total
Acer pseudoplatanus	15	15	32	62
Alnus glutinosa	39	1	1	42
Alnus viridis	0	4	0	4
Betula pendula	26	2	9	37
Betula pubescens	31	6	25	62
Carpinus betulus	20	0	4	24
Castenea sativa	30	0	4	34
Corylus avellana	0	0	8	8
Eucalyptus sp.	4	0	0	4
Fagus sylvatica	17	19	36	72
Fraxinus excelsior	30	31	18	79
Ilex aquifolium	0	0	6	6
Populus nigra	13	0	0	13
Populus tremula	1	0	0	1
Prunus avium	2	2	2	6
Quercus petraea	2	24	2	28
Quercus robur	31	55	50	236
Quercus rubra	2	0	0	2
Salix sp.	0	0	1	1
Sorbus aucuparia	5	4	1	10
Tilia cordata	0	2	0	2
Ulnus glabra	2	0	0	2
Ulnus minor	0	0	9	9
Other broadleaves	28	2	6	36
Abies alba	1	0	0	1
Larix decidua	28	0	0	28
Larix kaempferi	63	0	3	66
Picea abies	48	0	0	48
Picea sitchensis	507	0	7	514
Pinus contorta	126	0	0	126
Pinus nigra	31	0	0	31
Pinus radiata	0	0	6	0
Pinus sylvestris	210	0	26	236
Pseudotsuga menziesii	62	1	8	71
Thuya sp.	3	0	0	0
Tsuga sp.	3	0	0	0
All broadleaves	298	167	214	679
All conifers	1082	1	50	1133
Total	1380	168	264	1812

In Britain, several of the tree species are represented in the sample by a single individual. Furthermore, the sample reflects the age distribution of British trees. This means that older trees, which are of particular interest in pollution studies, are poorly represented. An alternative sampling scheme therefore seems desirable and Britain conducts a second survey restricted to a limited number of important species using a stratified random sampling design (Innes & Boswell 1987, 1988, 1989). Strata are defined by species, stand age and geographical region, ensuring that adequate representation of each target species is obtained in the areas of interest. Such a survey produces data representative of each stratum, but the data may not be representative of forests in the country as a whole.

ASSESSMENT

In most European studies of tree 'health', the two indices that are most frequently reported are defoliation and discoloration. Defoliation has been variously referred to as crown density, needle or leaf loss and crown transparency. It is assessed by estimating the amount of light passing through the crown, usually in relation to photographic or site standards (e.g. Bosshard 1986). Assessments were initially made in a number of unequal sized classes (0-10% loss of foliage, 11-25%, 26-60%, dead) but most countries now assess defoliation in 5% classes; the EC has recently approved a regulation making assessments in 5% steps compulsory for their international programme. As discoloration is more difficult to assess, the uneven-sized categories have been retained.

The method is subjective in that, like all estimates and most measurements, it is prone to bias. However, rigorous use of standards and detailed training can reduce this bias to an acceptable level (Schöpfer 1985, Neumann and Stowasser 1986, Innes 1988b). For example, in Britain, mean differences between the control and survey crews is less than 1%, with 95% of the individual observations of the survey crews lying within ±15% of the controls' observations.

Defoliation and discoloration are just two of a number of different indices that can be assessed. They are the only two that are required under the EC and UN-ECE protocols, but many countries now make more detailed assessments of individual trees. A variety of different measures can be incorporated; the possibilities are well-illustrated by the data collected for the Canadian ARNEWS programme (Magasi 1988) and the National Vegetation Survey of the U.S. Forest Response Programme (Alexander and Carlson 1988).

ANALYSIS

Only a very limited amount of analysis of survey data is undertaken in most countries. There are various reasons for this, the most frequently cited being that the standard of observation is not of sufficient quality to enable rigorous statistical analysis. However, the standard of the data from many surveys is comparable, if not considerably better, than much of the experimental work that has been undertaken and the quality of the data should not therefore present a problem.

Normally, data are summarised in a standard format, using the old 5-category classification described above. This format has a number of severe limitations and the information loss that is involved can lead to results being misinterpreted (Innes and Boswell 1990). It is now clear that the most important changes in tree condition usually occur in defoliation category 2 (25-60% loss), yet the large size of this group means that many subtle changes will be missed. The switch to 5% categories should go a long way to resolve this, provided that the data are not simply aggregated into the old classification.

More detailed analysis of suitable survey data is possible. Provided that sample sizes are adequate, it may be possible to relate the crown condition of trees to environmental factors, including pollution. This approach has been adopted in Britain since 1984 (e.g. Binns *et al.* 1985, 1986) but with limited success. Essentially, indices of tree condition have been derived for each site and these have then been related to measured or modelled environmental parameters using correlation and regression analysis. Similar studies have also been done elsewhere in Europe (e.g. Hauhs and Wright 1986, Krause 1987, Kandler 1989). The approach has many problems and some of these are outlined below.

A choice of a number of indices of crown condition exists. If defoliation and discoloration alone have been assessed, the choice lies in using the number of trees above a certain threshold or calculating a mean defoliation or discoloration score for the stand. The latter involves less loss of information but does not adequately cover the large variation in tree condition that frequently occurs within a sample of 24 trees. When a variety of different parameters have been assessed, it may be possible to use multivariate techniques to create an index of tree condition for a site but, so far, this technique does not appear to have been fully developed.

Major problems exist with the use of environmental parameters. It is impractical to measure these at all sites and, consequently, models have to be employed. The accuracy of the models is rarely known or tested although there has been a recent tendency to rectify this deficiency (e.g. Metcalfe *et al.* 1989, Derwent 1989). Even if an environmental parameter can be modelled for a site, it is virtually impossible to define the dose received (for pollutants) or the microclimate experienced by the trees. Problems also exist as to which index to use: climate and pollution can be characterised by a wide variety of indices and the number of explanatory variables can quickly outstrip the number of response variables.

As a result of these problems, traditional statistical techniques may not be the ideal approach. One possibility is to map indices of tree condition for a region or country and then relate the maps visually (or statistically) to maps of environmental parameters. This may enable anomalous areas to be identified, which can then be followed up in more detail. Even this approach has problems. Tree condition is extremely variable and adjacent stands may be very different. This means that the construction of maps can be complicated. However, it is possible to apply geostatistical techniques to assess the reliability of maps of crown condition (Innes and Boswell 1989) and indices that show no regional trends can be discounted from further investigation.

INTERPRETATION

The results obtained from surveys of forest condition have been widely misinterpreted. one of the most fundamental issues involved is the definition of a "damaged" tree. Reports frequently refer to the proportion of damaged trees within particular countries, yet these proportions can vary considerably depending upon how damage is classified. For example, Blank *et al* (1988) have shown how the proportion of damaged trees in the Federal Republic of Germany has fallen from about 50% to about 20% as the result of the threshold for the definition of damage being raised from 10% defoliation to 25%. There is little justification for adopting a threshold of 25% defoliation. The most appropriate figure would be the one at which significant increment loss started to occur. However, this is known to be variable (Innes and Cook 1989), depending on a variety of factors such as crown size and shape, tree age and rate of growth (e.g. Schlaepfer 1986). Consequently, it would be very difficult to implement.

The figures published for a given year are frequently assumed to indicate that decline in tree health has occurred. This is not necessarily the case. It is not possible, on the basis of a single survey of defoliation and discoloration, to identify a decline in tree health. A number of years are required; just how many remains uncertain.

THE ROLE OF AIR POLLUTION

It is sometimes alleged that the results of surveys of forest condition indicate the extent to which air pollution is affecting forests. This is simply not true. Neither defoliation nor discoloration are specific to damage by air pollution. Both are brought about by a variety of causes, of which air pollution is only one. Consequently, the results reflect the sum of factors affecting tree condition. Some authors have argued that any defoliation above the 25% threshold represents damage by air pollution but this is also untrue and highly misleading. While some defoliation around point sources can be directly attributed to the effects of pollution, there are very few examples where effects have occurred on a regional scale.

CONCLUSIONS

The condition of forests in Europe, North America and elsewhere has been of considerable concern over the last ten years. However, the massive decline in tree health that some predicted has not materialised and detailed experimental research is beginning to suggest that air pollution is not as important a factor in forest health as previously thought. Surveys of forest condition do not provide evidence of an air pollution effect and have not been conducted for long enough to identify any long-term trends in forest condition. There are numerous problems associated with the interpretation of survey data but, provided that these problems are recognised, surveys can produce extremely valuable information. In view of the many environmental problems that face trees, the continued monitoring of their condition should be seen as a priority in forest research. However, it is important to ensure that value of the data is not diminished by the misinterpretation of the results.

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EFFECTS OF AIR POLLUTION ON FOREST GROWTH IN SOUTHWESTERN GERMANY
- HUNTING FOR A PHANTOM? -

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ABSTRACT

FDC: 425.1: 425.3: 181.45: 181.65: (430.1)

Air pollution effects on forest ecosystems depend on types of pollution, site conditions and sensitivity of trees and stands. The question is: Have tree growth rates been influenced?

First results of growth analysis on trees with different needle losses suffered widely from problems with methods and interpretation of measurement results. Differences in growth rates due to stand dynamics were misunderstood as "forest damages".

There is evidence for widely better growth in Southwest-Germany and the adjoining regions of France and Switzerland, which means improved site conditions. The reasons were assumed in a combination of atmospheric depositions, especially nitrogen mineralisation due to climate and silviculture, CO_2-increase in the atmosphere and more favourable climatic conditions for decades.

Today we become aware of the methodic problems when testing growth and its correlation with forest damages. A reliable interpretation of dendrometric data seems possible if longer lasting measurement series of characteristics of the ecosystem's performance will be available.
Key words: Air pollution, forest growth, site conditions, forest decline

INTRODUCTION

Since the beginning of the 80s, thinning of tree crowns has been observed more often in Southwestern Germany on fir, spruce and later on also on beech and oak. They gave cause for concern about the forests' state of health.
In the beginning, dry years (e. g. 1974, 1976, 1979, 1983, 1984) were considered as the cause.
But later on air pollution which has increased by anthropogenic influence was made more and more responsible of the symptoms in the tree crowns. It was additionally said to be dangerous for growth and sites of forest trees.

From this point of view growth analysis received attention and discussions, as it had never done before: For growth is a measurable manifestation of performance capacity of sites or ecosystems. At the same time, they deliver information on the physiological activity of forest trees.

The following questions were of primary interest:

1. How are symptoms on tree crowns (= crown thinning) linked to growth trends?
2. What impacts are to be expected on the volume increment referred to a certain surface?
3. Do the actual growth rates of trees differ with those of former or previous stands?

The research results on the first question have often disconcerted when on the one hand "increment decreases" (SCHÖPFER and HRADETZKY 1986) and "positive changes in the whole" (KENK 1986 et al.) on the other hand have been stated. The many-sided causes for these findings could be research objects, applied methods and interpretations of results of measurements.

Nevertheless a clear and essentially identical impression of the whole has been gained.

STATE OF CROWNS AND GROWTH REACTIONS

State of crowns and (radial) growth indicate vitality of a tree. Both vary within a large scale but are rather closely correlated. They are strongly influenced by the genetic constitution, by the site, the supply with water and nutrient elements, by sylviculture as well as by biotic and abiotic influences.
Different states of crowns and corresponding differences of stand growth are primarily caused by competition between trees for growth factors. Only a more and more limited number of trees can achieve the physiological optimum and the corresponding growth at all. Its physiological field of tolerance is genetically determinated. It declines with age. During the total life of a stand, there are trees degrading socially. They die as long as forestry does not intervene in advance.

The extension of this social differentiation depends mainly on the site, the forestry operations and the weather.
Survens on seven long-term experimental plots with uneven aged forests with spruce, fir (and beech) in the Black Forest presented nearly linear correlations between crown lengths and diameter increment during the last five years; at the same time defoliation was reduced with increasing crown length (SPIECKER 1986).

The differring growth trends of "damage" classes, that is to say of damage appearance which is differently manifested and generally unspecified particularly crown thinning), and the trends of corresponding growth differences indicate ± long past weather extremes as the main release factor (KREMER 1985, KENK 1986, 1988). They are therefore no increment damages or increment deficits but the result of the mentioned social differentiation of stands.

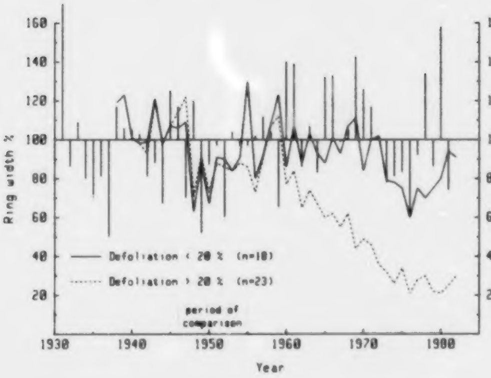


Fig. 1: Precipitation in the growing season and tree-ring widths (KREMER 1985) in relation to the comparative period 1946-1955
The vertical lines on the abscissa indicate the precipitation of the growing season in percentage of many years' mean. Many times, increments decrease in the long term after years with extreme weather conditions. Firs that are described as "damaged" today (high rates of crown thinning) had been obviously already damaged decades ago and growth continued decreasing permanently.

At present, it cannot be said at which point this differentiation exceeds the "normally" expected rate according to site, forestry operations and weather.
Limits to this rate can be set at the most by approximation, e. g. by periodic volume increment referred to the surface.
But even so the extremity cannot be indicated exactly.
For the annual variations and variations of periodic growth around ±30-50 % and more are known to be usual.

We have tried to derive from long-term experimental plots connections between average grades of crown thinning and periodic volume increments. In 60-100 years old spruce stands with average needle loss up to nearly 30 %, in fir stands up to 40-50 %, no increment reactions were found which exceed the known average caused by weather and/or operations.
These values pass by far the average needle loss that had been detected in terrestrial forest damage surveys.

Even in spruce stands at high altitudes of the Black Forest with obvious needle loss and partial yellowing, the actual volume increments of 55-95 years old stands lie inbetween 70-140 % of expected values of yield tables, and in average still over the level that had been stated in former times for this growth area (KENK 1987).

GROWTH AND CLIMATE

Climate and weather play a key role for the variation of tree growth and for the differentiation of trees in stands. Meanwhile a great deal of statements have been presented to this subject (BECKER et al. 1990).

Particularly approaches to the correlation between climate and growth by regression analysis have to be emphasized here, as they had been applied for the first time by BECKER in 1987 for annual increments of fir in the Vosges. The local climate values can well explain the annual variation of the growth and its long-term tendencies. But they reveal also very clearly the occurrence and the impacts of extreme weather incidences or obviously favourable factors to growth. KONNERT 1989 could demonstrate this by a positively changed growth trend for the long-term impacts of temperature fall and cold winter temperatures in 1956 on firs in Baden-Württemberg.
This seems worth noticing, when 40-60 % of the annual growth variation can thus be explained after all.

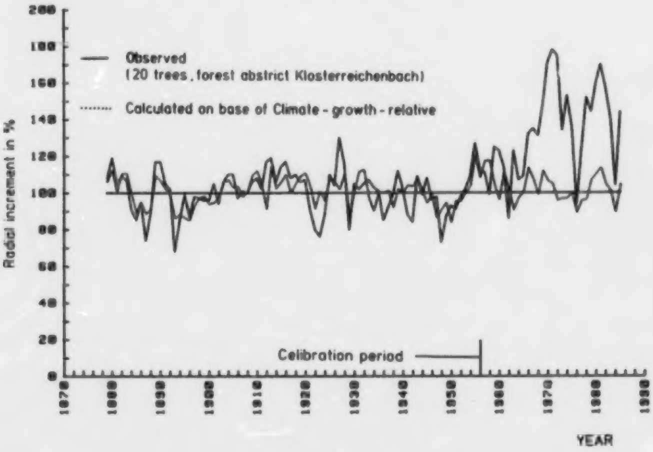


Fig. 2: Growth trend of spruces in the Northern Black Forest (KONNERT 1988). In the last years, values calculated by the relation between climate and growth are inferior to those achieved in reality; this can be understood as a hint on effects that additionally favor growth.

GROWTH LEVEL AND INCREMENT LOSS

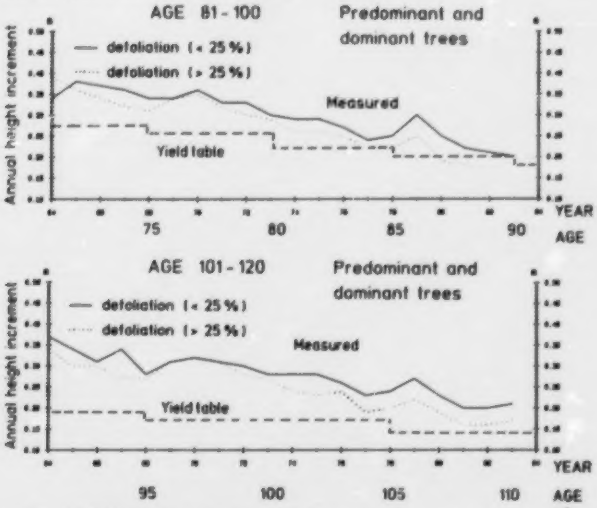
The performance capacity of sites changes locally and by time. In former times, the negative influences of forest grazing, forest litter utilization, soil disease, manner of land management and climatic change were discussed. Today, the centre of interest is the atmospheric deposition.

If we consider growth as an ecosystem indicator, we can recognize changes basing on long-term dendrometrical series of measurements and determine their dimension and directions by the differences (KENK 1986, 1987).
This is true for the actual growth level, the same as for that of former stand generations. Increment loss would then have to be stated if negative differences of today's and former growth trends could be noticed and could not be relied to influence factors working since then already.

Growth differences between damage classes are generally no "increment loss" but to a certain extent a "normal" result of the natural differentiation and sylvical management.
Actually, periodic volume increments of tree species and growth areas show the following picture during the past decades:

In the last decades, Picea abies Karst. deviates clearly up to higher limits at low and medium performance grades, due to the site, as has been known since then in yield tables by WIEDEMANN 1936/1942. From middle aged classes onwards they are generally for about 20-40 % higher than should be expected from site and performance investigations.

Results of the increment inventory on the occasion of the Terrestrial Forest Damage Inventory 1983 in Baden-Württemberg confirm the high performance level.



i_h Y.T. ASSMANN-FRANZ 1963, Site index M 40 (m.a.i. = 18 cum ha^{-1} yr^{-1})

Fig. 3: Height shoot lengths of spruces in TWI 1983 (Terrestrial Forest Damage Inventory).
Particularly in older stands, the height increments of the analyzed trees exceed clearly the best quality class of yield tables by ASSMANN/FRANZ 1968.
Do differnces in increment on this high performance level have to be regarded as "increment damage"?

Abies alba Mill. achieves nowadays again the long-term averages. For Pinus sylvestris L. and Quercus ssp., we have the impression of "normal" growth, that is to say growth corresponding to long-term averages.
Fagus sylvatica L. seems to react like Picea with considerable increases in growth.

Comparing former generations and subsequently today's stand generation, the series of measurements do not yet overlap in some cases.
But it becomes already evident that the actual level of performance according to height growth is obviously better today, the capacity of performance of sites therefore higher.
This is also indicated by the radial increment: The trees with dominant height in the subsequent stand have a more favourable development of diameter than the average of the 100 dominant trees of the previous stand.

But better care for the stand could just the same play a role causing this feature.

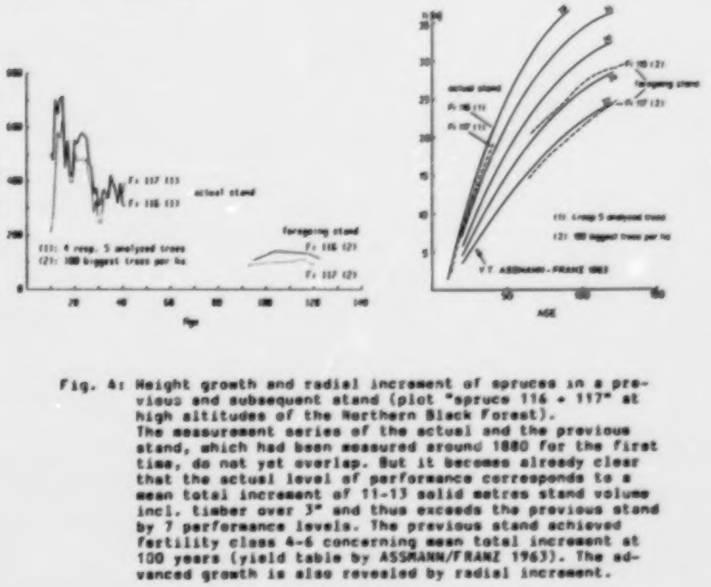


Fig. 4: Height growth and radial increment of spruces in a previous and subsequent stand (plot "spruce 116 + 117" at high altitudes of the Northern Black Forest).
The measurement series of the actual and the previous stand, which had been measured around 1880 for the first time, do not yet overlap. But it becomes already clear that the actual level of performance corresponds to a mean total increment of 11-13 solid metres stand volume incl. timber over 3" and thus exceeds the previous stand by 7 performance levels. The previous stand achieved fertility class 4-6 concerning mean total increment at 100 years (yield table by ASSMANN/FRANZ 1963). The advanced growth is also revealed by radial increment.

DISCUSSION

The results of our growth analysis in Baden-Württemberg do not give a hint on reduction of growth, but on changes of the site that are favourable towards growth.

The average crown thinning does not allow conclusions on reduced growth rates. The effects of atmospheric deposition do not generally head towards damage under our conditions.
In so far a phantom has been hunted. The site changes that are favourable towards growth are supposed to take place by intercorrelation of different factors: atmospheric deposition, especially of nitrogen, higher mineralisation by higher temperatures in the second half of the 40s, CO_2 increase in the atmosphere, and - last but not least - remarkably increased mean annual temperatures and precipitation (FISCHER and KONNERT 1989).

Higher growth rates and in the meantime evidently increased stand volume mean on the other hand also higher demands of water and nutrion supply.
Thereby the carrying capacity of sites can be surpassed. Thus we explain for example locally decreasing growth and destruction of stands at higher elevations of the Black Forest on soils in variated red sandstone. They are extremely poor of bases and additionally exposed to high stress from protone input out of the atosphere and to the negative effect of neglected care of the stocking (EVERS et al. 1986).

Especially such findings arise new questions about long-term effects of atmospheric depositions on forest ecosystems in my opinion. Their examination has just started especially when we particularly think of the additional impacts of increasing CO_2 concentrations, of climatic change and of the protone input which can be hardly reduced anymore.

Our conclusions for forestry practice in Baden-Württemberg relate to forest inventory and sylviculture: forest inventory has to consider increased growth for the calculated logging quantity. It will have to coordinate in an even more differentiated way stand volume and mixture of tree species with performance and carrying capacity of sites, thus contributing to minimize risks. Sylviculture has to fulfill similar tasks: composition of tree species and tree numbers affect also sites and the direction of changes. On sites that are poor of bases, lower tree numbers have to be utilized when establishing and caring for stocks, and higher parts of hardwood species and possibly fertilization have to be applied if usual production rates shall be kept consitent.
Finally, the obvious correlations between crown length, needle loss and growth underline the necessity of early and rather even stronger, consequent operations supporting the best stand components. This may at the same time contribute to stimulate the vitality of trees and stands.

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Abbreviations: AFZ = Allgemeine Forstzeitschrift; AFJZ = Allgemeine Forst- und Jagdzeitung; KfK-PEF = Kernforschungszentrum Karlsruhe - Projekt Europäisches Forschungszentrum für Maßnahmen zur Luftreinhaltung

THE HARMONIZED FOREST DAMAGE SURVEY IN EUROPA - ACHIEVEMENTS, SHORTCOMINGS AND FUTURE DEVELOPMENTS

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FDC: 425.1: 425.3: 181.45--05

The International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) is one of 5 Cooperative Programmes under the Geneva Convention on Long-Range Transboundary Air Pollution charged with assessing the various impacts of air pollutants on forest ecosystems.

The ICP Forests started its work in 1985 and in 1986 and adopted a manual of survey instructions, specifying essentially two levels of activities.

1. a representative, systematic survey of defoliation/discoloration in spruce, pine, fir, oak and beech;
2. intensive investigations of causes and effects of air pollution on forest ecosystems.

Since 1986 the ICP Forest has conducted four harmonized forest damage surveys in Europe, with 25 countries participating in these activities in 1989.
So far the surveys consist of the visual estimation of loss or discoloration of foliage in coniferous and broadleaved trees, according to harmonized sampling and classification procedures.

The very simple, although subjective assessment of foliage loss is rapidly performed on the same, numbered trees by foresters thoroughly trained prior to the annual field season which lasts from 15 July to 30 August each year.

The simplicity of the survey method and the systematic distribution of sample plots in grids between 1x1 km and 16x16 km wide provide an instantaneous picture of the defoliation situation across Europe at the end of each summer.

However, the essential question, to what extent loss of foliage is caused by air pollutants, cannot be answered by this type of survey. This is a serious handicap for a survey of forest condition initiated because of air pollution risks.

To overcome this disadvantage the ICP Forests in 1989 decided to prepare a forest soil survey including soil chemical and foliar analyses on a subsample of the existing network of survey plots in order to obtain a better understanding of causes and effects in forest decline.

In cooperation with the International Programme on Integrated Monitoring the necessary steps are taken to set up a system of permanent observation sites capable of monitoring forest health, air quality and changes in environmental conditions due to air pollutants and natural factors.

The considerable costs involved in setting up, operating and maintaining such a monitoring system and evaluating intelligently the constant flow of data make international cooperation and methodical harmonisation an indispensible precondition.

Forest declines in Japan: mature *Cryptomeria japonica* declines in the Kanto plains

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FDC: 425.1: 425.3: 181.45: 174.7 Cryptomeria japonica D. Don: (52)

It is reported that mature *Cryptomeria japonica* D. Don stands in the Kanto plains have declined recently. *C. japonica* as well as *Chamaecyparis obtusa* are dominant tree species for man-made forest in Japan. *C. japonica* is important in the timber industry because of the quality of its wood products. *C. japonica* in the Kanto plains have been planted in shrines and temples yard for religious environment and in farms as timber property. The declining of the mature *C. japonica* in this districts is not elucidated. Reportedly, acid rain is a major factor affecting *C. japonica*. There is no evidence to explain the acid rain effect on mature *C. japonica* decline in the field.

Materials and Methods

Extent of damaged trees in the Kanto plains.

Survey of Forest damage was carried out in 1985 and 1986 under the urgent task of Environment Agency. Tree damage of living trees was classified into three categories; (1)slightly damaged; leaf mass decrease in the top of crown, (2)moderately damaged; damage in the upper crown, and (3)severely damaged and dead; second category to dead of tree. Damage classification was done about tree group as a stand. Isolated trees in town, road side, and garden were neglected because there are many reasons of damages from human and environmental factors.

Progress of damage in sampling plots.

Using aerophotographs at the intervals of around 5 years which were taken at a fixed time by Geographical Survey Institute, temporal and spatial changes of tree crown damage of individual tree in each plot were analyzed. Original aerophotograph of 1/10,000 of the sampling stand plot was enlarged to 1/2,500 for estimating damage. Tree crown damage was classified into three categories; (1)no damaged, (2)damaged in and around the top, and (3)damaged in the whole crown.

cc: Prof. Satu Huttunen
Dr. Werner Baltensweiler

Results

C. japonica decline in the Kanto Plains.

Tree crown damage was observed in only mature *C. japonica* trees with discontinuing height growth. Ordinal first symptom occurred in the upper tree crown with clearly decreasing leaf mass in the tree top. And then, these decrease of leaf mass developed in the whole crown and the dead of upper crown was observed markedly. Damage of mature *C. japonica* was severe and living *C. japonica* was not determined in the sphere of around 60 km from the central Tokyo.

Tree decline was observed in low elevation under about 100 m above the sea level in Ibaraki, Tochigi, and Chiba prefectures. Declining was developed over 100 m above the sea level in Gunma, Saitama, and Kanagawa prefectures. However, scattered declining stands were merely observed in high elevation over 200 m above the sea level in Kanagawa prefecture. We could not observed declining silvicaltural stands of *C. japonica* in the mountainous high elevation area. This tendency will be completely different from the forest declines in Europe and North America.

Severe declining was moved to the west and northwest from Tokyo (Figure 1), and the high rate of severe declining area to total was also observed in the northwestern direction. Declining was developed in the whole Kanto plains area. However, the damage made rapid progress in whole area and severely damage area made rapid progress in the northwestern direction as compared with the observatory by Yambe(1978) in 1974(Figure 1).

Aerophotographs analysis shows the decline started in 1970's and was in advance at present(Figure 2). The yearly progress of declining differs among sampling stands. Slight damages was observed in the stand along the Arakawa River. These stands were located in relatively wide forested area. Also, there was different damage classes in the same area. As in Figure 2, a stand which was surrounded by hardwood forest was healthy, and a stand with thin density was damaged markedly.

Changes in environment factors in Kanto plains.

(1)*climatic factors:* Annual precipitation had a tendency of decreasing in the Kanto plains and was about 1,000 to 1,300 mm after 1960's in comparing with the 1,200 to 1,600 mm in 1950's(Figure 3). Mean annual precipitation was at the lowest in the northwestern area from Tokyo and was under 1,200 mm(Figure 4). Lower annual precipitation was also observed in the northeastern area and was 1,200 to 1,300 mm. In those areas severe water deficit took place in summer and considerable damage was caused with the crops. Mean daily maximum air temperature in August was higher in inland area of the Kanto plains and was above 31 ℃ (Figure 5). Annual minimum air temperature was increasing gradually after 1960's in Tokyo and was in the same tendency in inland cities such as Kumagaya and Maebashi. Increasing minimum temperature will be due to the increasing heat sink of buildings and houses, and heat radiation from air conditioners as the results of expansion of cities and increasing of residential districts. Air humidity affects the water status and photosynthesis from transpiration change. Annual mean atmospheric vapor demand was increased markedly in the Kanto plains (Figure 6).

(2)*Air pollutants:* Sulfur dioxide concentration was higher in Tokyo and southeastern Gunma(Figure 7a). Nitrogen dioxide concentration was higher in Tokyo and Kanagawa and high concentration inclined to the western area of the Kanto plains(Figure 7b). The number of the days of oxidant concentration exceed the 0.12 ppm in one hour was the highest in the central Saitama and was higher in western Tokyo and southeastern Gunma(Figure 7c). If the all air pollutants will originate from the industrial activities along the Tokyo Bay and high traffic in or around central Tokyo, these pollutants would be transported mainly to the west and northwestern direction.

Monitoring system on pH of rain was recently established. As shown in Figure 8, minimum value of pH was 3.9, and the mean value in all monitoring plot in the Kanto plains was 4.5. Comparing the components of rain in the first 1 mm, relatively high concentration of sulfuric and nitric ions was observed in northwestern direction from Tokyo.

Discussion

Forest declining distribution and air pollutants maps are well corresponding. However, in the severely damaged area, there are concentration difference of air pollutants. In Tokyo and Kanagawa, nitrogen dioxide and sulfur dioxide are conspicuous, in Saitama, oxidant is conspicuous, and in southeastern Gunma, sulfur dioxide is conspicuous. These results suggest that the study of the complex effects of each air pollutant on forest declining is needed. Simultaneously, we have to consider the climatic changes in the Kanto plains. Yearly growth is affected by climatic condition, and it is very difficult to divide the damage which was affected by climatic stress and by air pollutant stress. Especially, interpretation of health of mature tree which ceased their height growth will be very difficult. Natural stand of *C. japonica* is distributed in wet climatic area with high precipitation of over 1,500 mm. It suggests that low precipitation of about 1,000 to 1,500 mm after 1960's, hot summer, and increasing atmospheric vapor demand will cause the water stress of mature *C. japonica* tree. We observed the low water potential of leaves and stomatal closure in a daytime of summer in mature tall tree which was located in unpolluted area in Ibaraki prefecture (Figure 9). As the another evidence of the climatic effect on mature tree survival, young planted *C. japonica* trees in severely damaged stand showed health and well height growth.

When we discuss about the declining of isolated forest in or outside city such as the stands in the Kanto plains, we have to consider the forest site conditions. Protected forest by surrounding forests was healthy and isolated thin forest was damaged(Figure 2). These results suggest that there are the possible effects of tree crown on air cleaning, and less damage will be expected in inside trees of a stand.

Possible effect of acid rain on tree damage is not clear. We do not observe the direct effect of acid rain on tree and crop leaves in the field. We only observe the spot damage on the flowers of azalea,morning-glory etc. Soil analysis in severely damaged stand indicates there were no change in soil property and acidity. Soils of the Kanto plains are very deep and the black soils derived from volcanic ash have high buffering capacity to acid rain(Ishizuka 1989). From these results, we can not explain the cause of damage by the acid rain.

Conclusion

Cause of mature forest decline of *C. japonica* in the Kanto plains is not clear. Possible causes are, (1)recent climatic changes; especially less rainfall and low air humidity, (2)gaseous air pollutants; not a single effect and the complex effects, (3)physiological properties of mature old aged trees; water stress of tree crown at higher position and decreasing photosynthetic products in the crown.

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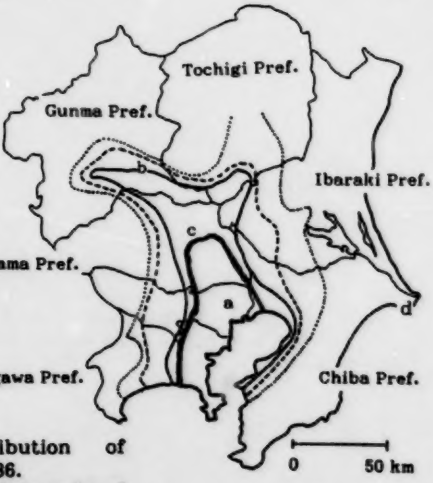

Fig.1 Forest decline distribution of *Cryptomeria japonica* in 1985 & 1986.
thick and thin lines: severely damaged and dead observed in 1974 by Yambe(1978) and in 1985 and 1986, respectively, chain line: moderately damaged, and dotted line: slightlydamaged. a: Tokyo, b: Maebashi, c: Kumagaya, and d: Choshi

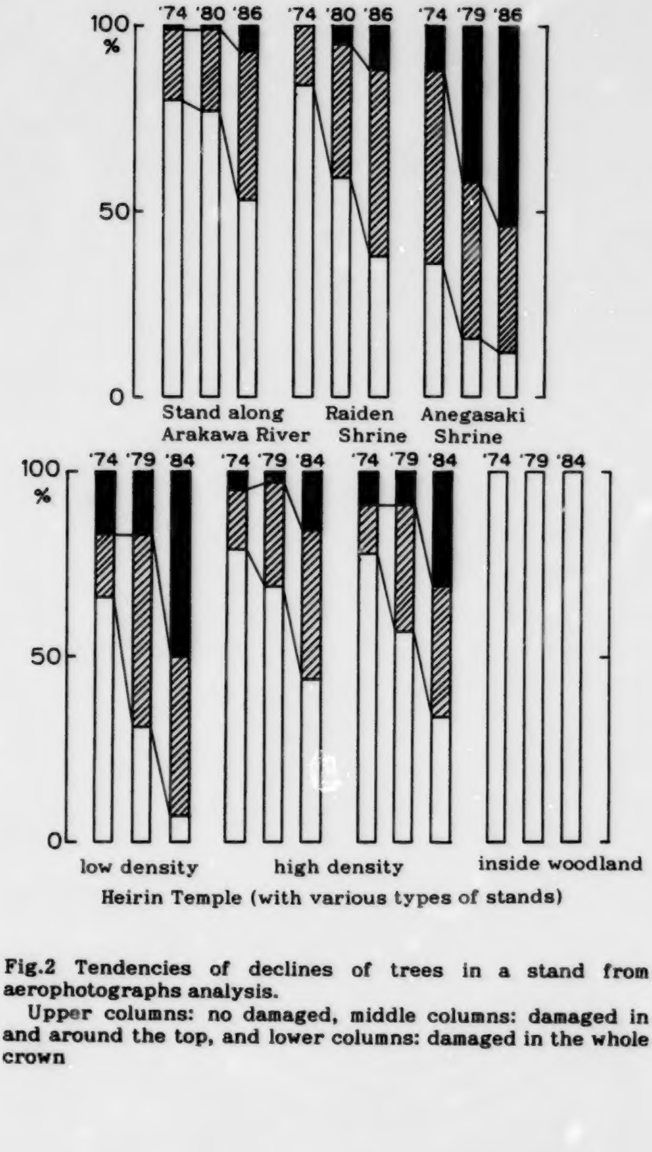

Fig.2 Tendencies of declines of trees in a stand from aerophotographs analysis.

Upper columns: no damaged, middle columns: damaged in and around the top, and lower columns: damaged in the whole crown

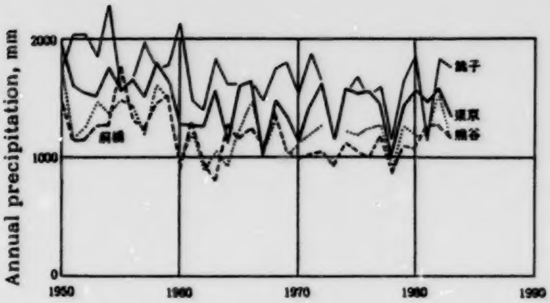

Fig.3 Yearly changes of annual precipitation.
Thick line: Tokyo, chain line: Maebashi, dotted line: Kumagaya, and thin line: Choshi. Choshi is far from Tokyo and is along seaside. We select the city as control because of isolation from influence of air pollutants.

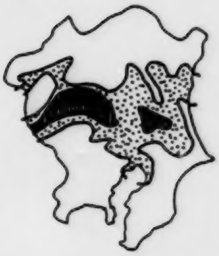

Fig.4 Distribution of annual precipitation in the Kanto plains (Morikawa, 1989).
painted: below 1,200 mm, lines: 1,200-1,300 mm, and dotted: 1,300 -1,400 mm

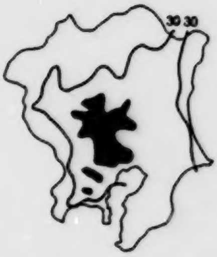

Fig.5 Distribution of daily maximum air temperature in summer in the Kanto plains(Morikawa, 1979).
painted: above 31° C

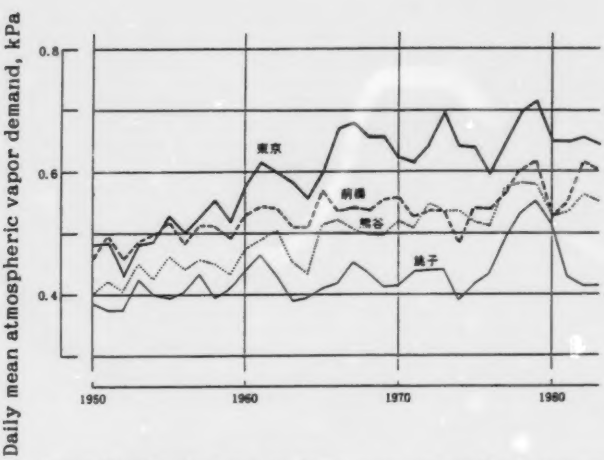

Fig.6 Yearly changes in daily mean atmospheric vapor demand (Morikawa, 1989)
Symbols are the same as Figure 3.

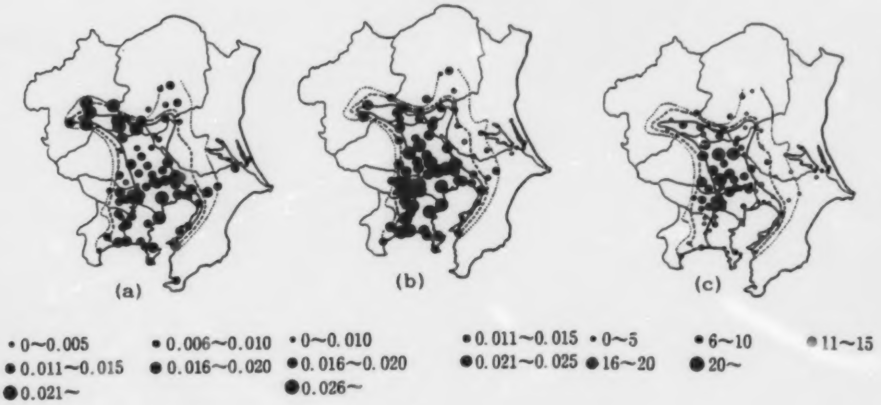
(a)
(b)
(c)
• 0~0.005
• 0.006~0.010
• 0.011~0.015
• 0.016~0.020
● 0.021~
• 0~0.010
• 0.011~0.015
• 0.016~0.020
● 0.021~0.025
● 0.026~
• 0~5
• 6~10
• 11~15
• 16~20
● 20~

Fig.7 Mean annual sulfur dioxide(a), nitrogen dioxide(b) concentrations in ppm, and days exceed 0.12 ppm in one hour of oxidant in a year(c) for 1974-1978.
Lines in the figures are the same as Figure 1.

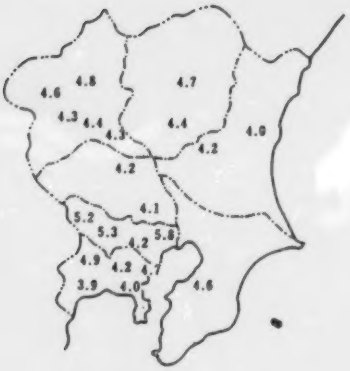
4.6
4.8
4.7
4.3
4.4
4.3
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Fig.8 Mean pH of rain in 1986.

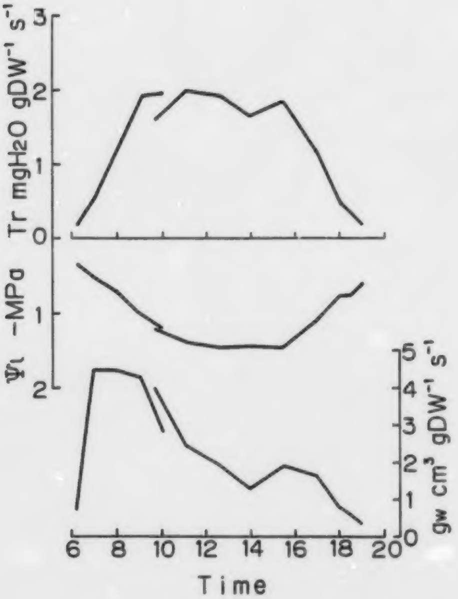

Fig.9 Diurnal trends of transpiration (upper), leaf water potential(middle), and stomatal conductance(lower) in the top of crown of mature *C. japonica* with the height of 25 m on clear summer day.

INTEGRATED MONITORING IN SMALL WATERSHEDS - A WAY OF UNDERSTANDING LONG TERM EFFECTS OF AIR POLLUTANTS IN THE NORDIC COUNTRIES

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FDC: 425.1: 425.3: 181.45

SUMMARY

The anthropogenic influence on the gaseous composition of the atmosphere, on the dry and wet deposition of acids and nitrogen, on the distribution of heavy metals and hydrocarbons are causing complex effects in nature. The yearly variation of climate is a driving variable that has an impact on most other anthropogenic and biological factors.

To understand causal relations between anthropogenic stress factors and the natural behaviour in a long term perspective integrated ecological monitoring in small catchment areas is under development in the Nordic countries. The connections between input and output of elements, soil water and soil chemistry, climate etc are registered to understand effects on primary production, needle nutrients and species composition. Examples are given to indicate the expected relations and evaluations that are possible to extract in the future from these observations.

Keywords: Integrated monitoring, catchment, deposition, nutrient levels, soil chemistry, acidification, nitrogen deposition, heavy metals.

AIR POLLUTION STUDIES IN USSR FORESTS

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FDC: 425.1: 425.3: 181.45: (47)

SUMMARY

The review has analysed the main trends in the study of forest gas resistance in the USSR. The aggravation of the ecological situation in some regions of the country has been caused by excessive concentration of industrial enterprises. Acid gases are the main air pollutants responsible for phytotoxic effect. Physiologo-biochemical investigations are aimed at elucidating the supply, migration and removal of toxicants in/from plants, the mechanism of their effect on assimilation processes, secondary metabolism, reparation and general tree productivity and their synergism. The dynamics of tree resistance in terms of the conditions of tree growth and availability for colonization by different groups of consumers is used as a basis for monitoring of weakened forests. The ways of enhancement of stand resistance to industrial emissions have been also discussed.

Keywords: Forest ecosystem, phytotoxicant, metabolism, resistance, consumer, monitoring

Social Aspects

Along with forest protection against fire, pests and diseases, the problem of stand protection against strong impact of industrial air pollution has become recently very important in the USSR.

Up to the late 1950s establishing and management of nature preserves with unique fauna and flora formed the basis for the national system of nature protection in the USSR. The nature as human environment was not adequately protected and the experience of industrially developed countries in this field was not taken into account (Fedoseev 1989).

In designs of industrial enterprises the main attention was paid to the maximal cost reduction of the end production. It resulted in the irregular disposition of industry over the whole territory of the country, in concentrating the industry close by mineral and energy resources in regions with highly developed civil-engineering and transport network. The preference was given to the construction of giant plants. It was not unusual that industrial enterprises emitting various toxic substances were constructed close to each other which produced toxicant synergic effect on vegetation. All these facts are responsible for crisis ecological situation in a number of regions of the country.

Air Pollution of Forests

The map of sulphate distribution in snow cover generally shows the degree of pollution in the territory of the USSR (Figure 1). The highest pollution is observed in western regions (which is somewhat related to trans-border transport of pollutants) as well as in the Ukraine, central regions of the european part of the USSR, the Urals, Southern Siberia and some other industrial regions.

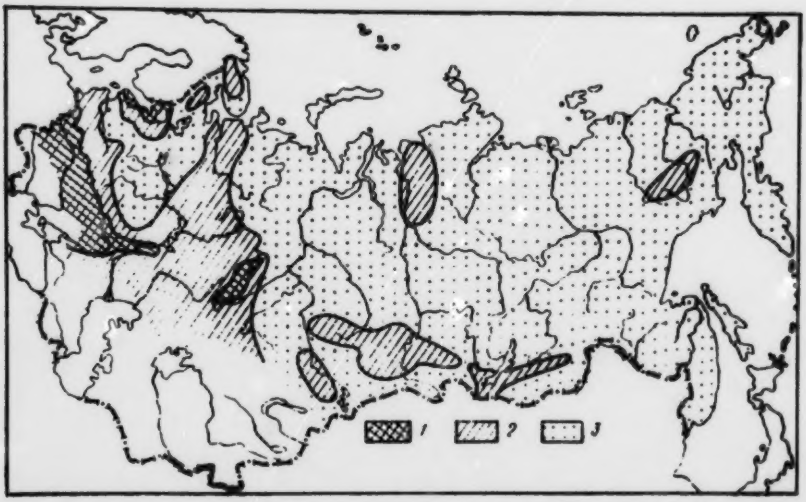

Figure 1: The distribution of the concentrations of sulphate ion in melting snow water in the territory of the USSR. 1,> 8; 2, 4-8; 3, 0-4 mg/l (From Belikova et al. 1984).

The primary pollutants in the USSR are sulfur-containing compounds. The total sulfur content in industrial emissions is 11.8 million tons per a year (Belikova et al. 1984). Taking a total amount of annual wastes of sulfurous anhydride as 100%, an amount of other main pollutants can be arranged as follows: nitrogen peroxide - 26%, carbon monoxide - 5%, hydrogen sulfide - 4%, phenol - 2%, hydrocyanic acid - 2%, fluorine compounds - 2%, carbon disulfide - 2%, chlorine - 1% and ammonia - 1% (Styrikovich, Vnukov 1984).

Since 1960 some vigorous measures have been provided to collect gaseous and dust emissions of industrial plants. In the recent decade the designs of industrial plants have been examinedin terms of ecology by government services. Public health standards of maximum permissible concentrations of pollutants in the air of populated regions are taken into account in designs of industrial works. Yet many plants show several-fold greater susceptibility to the most of toxicants than homeotherms (Table). Hence, the designing itself has been involved in the process of injurious impact of industry on forests vegetation.

The dynamics of gradual disappearance of coniferous forests surrounding Bratsk city (Eastern Siberia) shows space and time characteristics of these phenomena. Fluorides, which effect is enhanced by compounds of sulphur, nitrogen and chlorides, are primary air pollutants in this industrial region. The drying up of the stands started here since 1968, in a year following the start-up of the main industrial enterprises - an aluminium foundry and wood chemistry plant (Figure 2).

Table: Maximum permissible concentrations (MPC) of some air toxic compounds admitted in the USSR

Toxic compounds	MPC, mg/m^3			
	For man		For conifers (in Baikalsk region)	
	Single Maximum	Daily Average	Single Maximum	Daily Average
Nitric oxide	0.085	0.04	0.04	0.02
Sulfurous anhydride	0.5	0.05	0.3	0.015
Vapours of sylfuric acid	0.3	0.1	0.1	0.03
Chlorine	0.1	0.03	0.025	0.015
Hydrogen fluoride	0.02	0.005	0.004	0.0005

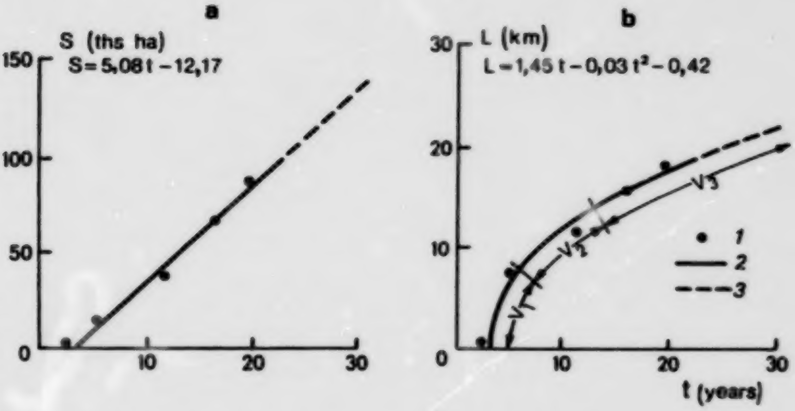

Figure 2: Area (a) and linear sizes (b) of the drying forest zone versus duration of air pollution effect. 1, data obtained; 2, dynamics calculated on the basis of the data obtained; 3, dynamics calculated for a further period.

Close rectilinearly relationship has been shown (Figure 2a) between the duration of air pollution effect (t) and the area of drying up (S) of pine (Pinus sylvestris L.) and larch (Larix sibirica Ledeb.) forests. It is suggested to remain the same in the nearest years (Rozhkov et al. 1989). An increase in linear extension of the drying zone (L) with the time factor (t) is thus described by a parabolic function. In the curve obtained (Figure 2b) one can differentiate three parts (v_1, v_2 and v_3) significantly differing in the rate of changes in tree state.

Rapid death of the forests in the initial period (v_1) is related to a sharp poisoning of trees. At present monotonous extension of the drying zone (v_3) is observed which is due to a cumulative effect of pollutants. In the heavy polluted zone (v_1) conifers died. Deciduous tree stands forming instead have clear symptoms of depression and are gradually substituted for more tolerant herb-bush communities. Due to such successions in vegetation, in spite of the persistent gaseous pollution, the toxicant injurious effect on the newly formed phytocenosis gradually decreases. Though it is followed by the reduction in dust and gaseous precipitating function of the vegetation due to general decline in biomass.

Phytotoxic Effect

Most of researchers relate the phytotoxic effect of air pollution to the intensity of gas exchange in plants. Resistant species are characterized with long-term vegetation, slow phenology, shorter period and degree of stoma opening during the day, larger amount of stoma per a unit of leaf area and the waxy cover and thicker cuticle in the leaves (Il'kun 1971). All these features reduce the intensity of toxicant supply.

The phloem way is shown to play a major role in the reduction of toxicant concentration when the plants are affected by acid gases. An experimental fumigation of pine (Pinus sylvestris L.) shows metabolically active tissues - needles and inner bark to be immediately saturated with fluorine; the same tissues release the toxicant most intensively (Rozhkov, Mikhajlova 1989). During periodic separation of the peripheral part of the inner bark, fluorine is transferred to the scaly bark and its concentration may be twice as high here than in the phloem. In the roots and sapwood fluorine concentration is increasing much slower than in the inner bark. Fluorine is transported to the sapwood in the upward efflux from the roots. Cations of potassium, sodium, calcium and magnesium are shown to play the main role in fluorine neutralization in plant tissues. Intensive fluorine removal via root system is observed at the end of summer.

There is no any pronounced specificity in the variation of physiologo-biochemical features under the effect of various acid gases. Their toxic effect on plants resultes in disturbance of the activity of many enzymes because of acidification of the protoplasm and disturbances in ion regime, in the change of organic compound metabolism and accumulation of ballast or toxic compounds, in destroying of photosynthetic structures and in unballancing of gas exchange. Lethal concentration of toxicants produces oxidative dissimilation of polymer compounds - starch, proteins and lipids. Altogether, acid gases are not specific inhibitors, their effect involving many metabolic processes and being similar to the effect of other extreme factors - drought, soil salinity, ionizing radiation and etc. (Nikolaevsky 1979).

The phytotoxic effect of organic air pollutants has been less studied. Alien phenols entering woody plants are shown to be of little mobility and localized in the organs which they directly contact. They accumulate mainly in peripheral, more damaged parts of the leaves. The mechanism of the toxic effect of phenols is based on excessive accumulation of intermediate products of their oxidation. Therefore, plants with leaves showing poor activity of polyphenoloxidase are more resistant to phenol compounds (Tarabrin et al. 1986).

Pyridine bases when being transported into the inner medium of the cell, bind molecules-receptors of pyridine. Being completely or partially blocked, the receptors lose their functions. It is followed by a disturbance in separate metabolic fluxes, while under excessive concentrations of the toxicant - by cell death.

The study of the joint effect of different pollutants is of particular interest though it is not very intensive yet. Low concentrations of pyridine is reported to decrease the toxic effect of sulfurous anhydride and phenol and high concentrations of the mixture of these compounds - to be more toxic than each of them separately (Tarabrin et al. 1986).

The experiments performed in field gas chambers with young conifers determined relative toxicity of some acid gases and their various combinations (Rozhkov, Mikhajlova 1989). According to the reduction of phytotoxicity, the gases tested can be arranged as follows: hydrogen fluoride, chlorine, sulfurous anhydride, nitrogen peroxide and carbon monoxide. When nitrogen peroxide or carbon monoxide is present in the air, hydrogen fluoride is a dominant toxicant. Its toxicity many-fold increases in the presence of chlorine and sulfurous anhydride. A mixture containing all tested gases is the most dangerous for plants since several synergic effects can be superimposed in this case.

Non-specific adaptation of plants to gaseous emissions is responsible for higher resistance to toxicants of species with xeromorphic features and phyllogenetically related to dry and saline soils (Il'kun, 1978; Kulagin 1985). Of great interest are also plant populations grown in areas with high natural concentrations of toxicants. Thus, the population of Dahurian larch (Larix gmelinii Rupr.) growing in a fluorite deposit proved to be promising for planting in the areas polluted by fluorine compounds (Rozhkov, Mikhajlova 1989).

Dynamics of Tree Resistance and Monitoring

Resistance variations due to different stress factors are often assessed in terms of tree availability for certain groups of consumers (Isaev, Girs 1975; Rozhkov 1981). Plants are shown to activate their physiological processes in the first stages of the effect of different unfavourable factors. One can observe hypertrophy of the leaf apparatus, increase in photosynthetic productivity and in defense substance accumulation (Rozhkov, Massel 1982; Barakhtenova, Nikolaevsky 1988). For some period the resistance of trees increases (Figure 3). However, the intensive metabolism is followed by depletion of reserve substances, decrease in the area of the leaf apparatus, deep inhibition of photosynthesis and reduction in the formation of defence substances. Hence, the resistance of trees declines and they are intensively colonized by the most aggres-

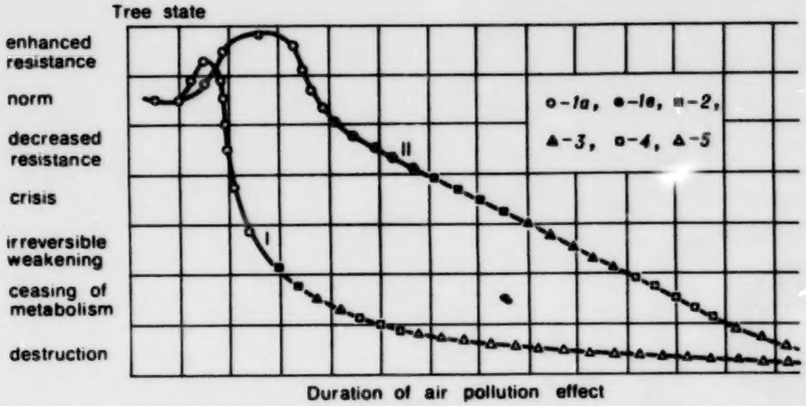

Figure 3. The dynamics of changes in resistance and succession of consumers under sharp (I) and chronic (II) poisoning of trees. Consumers of: 1, rather viable trees (a, usual population; b, mass outbreaks); 2, heavily weakened trees; 3, necrotic trees; 4, fresh deadwood; 5, decomposing wood.

sive species of consumers.

Further effect of unfavourable factors produces crisis in the state of the trees. It is expressed in premature ageing and death of shoots, breaking up or significant transformation of symbiotic relationships with mycorrhizal fungi and broadening of the range of consumers including species rather susceptible to the effect of defence substances and utilizing necrotic parts of plants (Pleshanov 1982; Volkova, Davydova 1987; Petrov 1989).

The irreversible weakening of trees is characterized by necrosis of a great part of the leaf apparatus, strong inhibition of photosynthesis, disturbance in root-leaf relations, sharp exhaustion of the tissue of defence substances, especially the most toxic compounds (Girs 1982). Xylophagous insects and tree destroying fungi are the most abundant among consumers of necrotic trees.

In each particular case the dynamics of the reduction in tree resistance due to air pollution is mainly determined by concentration and toxicity of pollutants, belonging of a tree to a certain systematic and ecologo-morphological group, by habitats and the activity of secondary injurious factors (Kulagin 1985). When the trees are severely poisoned, the resistance may fall so rapidly that the whole groups of phytophages fall out of a successional row of consumers and many species typical of severely weakened trees colonize only fresh deadwood (Anisimova 1989).

On the contrary, chronic poisoning of trees under moderate pollution produces gradual decrease in the resistance (Figure 3). Some additional factors of weakening are of great importance in this process. Extreme unfavourable weather conditions are shown to be responsible for a durable reduction in the resistance (Lovelius 1979; Aleksandrenko et al. 1987). In fir (Abies sibirica Ledeb.) forests in the south-eastern coast of Lake Baikal weakened by sulphur-containing emissions from the paper and pulp plant, mass outbreaks of xylophagous insects and fungi epiphytotics are mainly responsible for the crisis state of the trees (Isaev et al. 1988; Morozova et al. 1988).

Most of researchers assume that plants as recipients of various external effects show a limited number of responses under stress (Kulagin 1980). A universal and nonspecific nature of the latter makes it possible to predict tree resistance to air pollution in terms of their responses to other injurious factors.

Forest resistance to stress is mainly determined by species composition and inhabitat: deciduous forests with greater resistance to phytopollutants than conifers prevail in more heavily polluted south-western regions of the country. Conifer resistance, in turn, is of great geographical variation. In different habitats similar levels of air pollution result in an ambiguous phytotoxic effect.

The reduction in tree increment following single defoliation by phylophagous insects can serve as a peculiar test indicator of tree resistance used for ecological predictions. Thus in southern regions of Siberia larch damage by larch bud moth (Zeiraphera diniana Gn.) causes the reduction in wood increment for two years and in the forests of central taiga - for 7-9 years (Pleshanov 1981).

Obviously particular concentrations of pollutants may not decline tree viability in southern taiga zone, cause cumulative weakening of trees in central taiga forests and result in sharp poisoning and rapid drying up of trees in forest-tundra. Hence, there is a need for development of regional standards of maximum permissible concentrations of phytopollutants.

The situation is more complicated in mountain regions where areas of severe tree weakening can locate not only close to the sources of pollution but far away from them in particular landscape-ecological habitats. It depends both on specific dispersion of smoke plumes and stand habitats. The most pronounced effect is exhibited when both cases coincide. Such situation can be observed, for example, in the northern macroslope of the Khamar Daban (south-eastern coast of Lake Baikal) where the main source of air pollution is sulphur-containing emissions of the paper and pulp plant in Baikalsk city. The intensive drying up is observed here in high-mountain coniferous forests situated 900-1200 m above the see level where the inverse layer of air pollution is formed.

A comprehensive ecological monitoring of forests is recommended to precisely estimate and predict the state of forest vegetation. It consists of:

- control of the air and toxicant accumulation in soil and mapping of polluted areas;
- assessment of forests by visual symptoms of weakening of trees and bushes, degree of necrosis of leaves and shoots, characteristics of fruit bearing as well as variation in phytocenosis structure;
- mycological and entomological studies in stationary test plots;
- dendroindication and other morphometric estimations of trees and determination of pollen viability;
- biochemical analysis of toxicant accumulation in plant tissues, determination of pigments, amino acid composition, secondary metabolites (resinous and phenolic compounds) and other substances determining the level of tree resistance;
- estimation of bioproductivity and gas absorbing ability of stands.

The ecological mapping of polluted areas is a final step in the monitoring which is necessary for organization and performance of forest protection.

Promotion of Forest Resistance

Traditional approaches to the functional significance of forests and their management should be reexamined in view of long-term air pollution (Pleshanov 1986; Kulagin 1985). In the zone of low pollution, coniferous stands need to be regularly renewed and hence, forest exploitation here should envisage small-dimension assortment. In the zone of moderate pollution, it is advisable that the forests be gradually substituted for deciduous species having high gas absorbing ability. The intensive conifer logging is necessary to do first of all in old stands. In the zone of heavy pollution, it is necessary to promote rapid substitution of coniferous stands for deciduous ones avoiding the injury of deciduous species seedlings and soil mineralization.

Sanitary-hygienic importance of plantings adjacent to industrial enterprises is very limited. They mainly perform decorative functions. At the first stages of landscaping it is necessary that the forests be naturally restored by construction of solid defence tracks and roadside borders consisting of local and introduced species most tolerant to pollution. In future park forest management should be developed here by delivering rich soil from outside.

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UMUS DEGRADATION UNDER THE INFLUENCE OF SIMULATED "ACID RAINS"

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Abstract

The purpose of these investigations was to define the changes going on in soil under the influence of simulated "acid rains". It was achieved by treating three kinds of soil with water solutions with pH: 2,0, 3,0, 4,0, 5,0, 6,0, 7,8 for two vegetation periods.

As the result, in the examined soils differences were found in the pH of soils amounting to 2,5 of the unit, in the sorption complex the content of H^+ ions increased and the sum of bases decreased considerably. Significant changes in the number of bacteria, fungi, macromycetes were found - in the most acid soultions they decreased by 100%. The processes of nitrification, cellulose decomposition and soil respiration were reduced, whereas ammonification was stimulated. Under the influence of "acid rains" the content of carbon and nitrogen remained unchanges, while the content of both fulvic and grey and brown humic acids was reduced. Together with the increase in soil acidity grew the content of hymatomelanic acids. No significant changes in the content of bitumen, humins, humic carbon and the $Q_{4/6}$ index of colour were noted under the influence of simulated "acid rains".

1. Introduction

At present it is estimated that about three fourths of the earth's surface are under the pressure of anthropogenic factors influencing to various degrees all the habitat determinants. It refers mainly to the humus layer on the surface of which the elements emitted to the atmospheric air are deposited. Hence, in the humus layer of soil chemical and biochemical processes are the most intensive and they have a decisive influence upon the intensity and direction of the other soil processes. In recent times the impact of "acid rains" which bring about a quick rate of soil reaction change is especially worrying. Gradual acidification of soils determines the composition of soil microflora and influences the rate and direction of changes in the organic matter of soils, which leads to humus degradation.

Under the term of humus degradation we understand chemical and biochemical changes going on in its composition under the influence of anthropogenic factors which are contrary to the direction and rate of these processes in normal conditions, irrespective of whether the estimation of these processes made by man from the point of view of soil productivity has a positive or negative character.

The aim of the present investigations was to define, in controlled conditions, the changes going on in the humus layer of soils under the influence of only one variable, i.e. acid water solutions. It refers both to biological activity of soils and to the changes in isolated fractions of the soil humus.

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2. Material and Methods

2.1. Field Investigations

In order to weigh the impact of acid rains on the processes going on in the surface layer of soil, water solutions with pH: 2,0, 3,0, 4,0, 5,0, 6,0, were used. The water solutions were obtained by adding to water certain quantities of sulphuric acid. The values were referred to soils sprinkled with water from abyssal well with pH 7,8 which had been strained through a filter catching all kinds of suspension. The frequency of watering was synchronized with the days when there was atmospheric precipitation in spring and autumn months. In summer, on the other hand, i.e. from June to September 15th the pots received doses of water 2-3 times higher because the soil in the pots did not take underground water and was therefore subject to quicker drying. At the same time a roof was constructed cutting off the access to precipitation. Other meteorological factors were close to normal conditions.

The examinations were carried out in a nursery in Jodłówka. The influence of simulated "acid rains" on the fraction composition of humus was analysed on three kinds of soils, i.e. weakly loamy sands, dusty formations and on peats. Before watering of sands and dusty formations, pH oscillated around 4,6-4,8 in H_2O and 4,0-4,3 in KCL, while in peats it was 3,8-4,0 in H_2O and 3,6 in KCL. In mineral formations the content of organic matter was around 1,37-2,44, whereas in organic formations the content of organic matter was around 60,90-69,00%. The content of nitrogen in mineral soils was from 0,080 to 0,097%. The C/N ratio was around 10,9-14,7 and was more varied in sandy soils than in dusty formations. In peats the content of N was on the same level of 0,823% and the C/N ratio was 48,4.

The experiment was carried out for the period of two years. Thjis is too short a time to obtain explicit results, but it was a fragment of a broader experiment which had to be interrupted because of methodological reasons. Nevertheless, the experiment shows the current trends in humus degradation.

2.2. Analytic Investigations

2.2.1. Determination of the Content of Bituminous Connections in Soil

An air-dry sample of soil was ground in a porcelain mortar and sifted through a sieve with meshes of 2mm in diameter. The 50g of of mineral soil or 15g of organic soil was weighed and placed in Soxhlet's apparatus. A mixture of ethanol and benzene with the voluminal ratio 1:1 was extracted. After finishing the extraction process, the contents of the flask was distilled. After distilling benzene and ethanol, the remaining portion, which constituted the fraction of bituminous connections, was weighed and the result was reduced to the percentage in soil.

2.2.2. Determination in Soil of the Content of Humus Fractions Soluble in Alkalies, i.e. Fractions of: Fulvic Acids, Hymatomelanic Acids, Brown and Grey Humic Acids.

A soil sample deprived of bituminous connections (after extraction in Soxhlet's apparatus), i.e. 5g of organic soil or 20g of mineral soil was placed in a beaker with the capacity of 200xm^3. 100cm^3 of 0,1 NaOH was added and the mixture was stirred from time to time. After 4 days it was strained through a hard filter and the filtrate was acidified with

15cm^3 of 3% HCL. After 24 hours it was filtered. In the sediment (a) the content of hymatomelanic and humic acids was determined, while in the filtrate (b) the content of fulvic acids was defined, following the methods described below.

2.2.2.1. Determination of the Content of Fulvic Acids in Soil

50cm^3 of the acid filtrate (b) was alkalinized by means of 15cm^3 of 10% NaOH. In the solution obtained the content of fulvic acids was determined colorimetrically in monochromatic light with the wavelength of 465 nm.

2.2.3. Determination of Hymatomelanic Acids Content in Soils

The sediment (a) collected from the filter was dried in the temperature of 105°C for four hours and then extracted hot several times by means of ethanol. 40cm of alcohol were used for this purpose. The alcohol extract was filled up by means of 0,1 n NaOH to 50 cm^3 and colorimetrized in monochromatic light with the wavelength of 465 nm.

2.2.4. Determination of the Content of Brown and Grey Humic Acids in Soil

The sediment (a), after alcohol extraction, was dissolved by means of about 95cm^3 of 0,1 n NaOH. The solution obtained was filled up with water to 100cm^3 and colorimetrized twice: for the first time in monochromaticlight with the wavelength of 465 nm and for the second time in monochromatic light with the wavelength of 665 nm. On the basis of the extinctions obtainedfollowing the boundary numbers given by Hoffman (1965) and referring to brown and grey humic acids, the content of these connections was calculated.

2.2.5. Determination of the Content of Organic Coal in Soil

An air-dry soil sample was treated with 20cm³ of 0,4 n $K_2Cr_2O_7$ in a sulphuric acid solution (concentration of H_2SO_4 + H_2O with voluminal ratio 1:1) and heated up to boiling temperature for five minutes. After cooling, the solution was placed in a flask with the capacity of 50cm³ washed and filled up with water to the scale mark. Then it was whirled in order to obtain a limpid solution which was colorimetrized in monochromatic light with wavelength of 600 nm. As a control sample an acid solution of chromic salts was prepared.

2.2.6. Determination of the Humus Content in Soil

The content of organic coal in soil in % was multiplied bt the coeficcient 1,73 and the humus content in soil in % was received.

2.2.7. Determination of the Content of Humins and Humic Carbon in Soil

The sum of bituminous connections, fulvic, hymatomelanic, grey and brown humic acids was calculated and the sum obtained was substracted from the content of humus in soil.

2.2.8. The $Q_{4/6}$ Index of Colour

The value of extinction of alkaline solution of humus obtained in the result of the measurements in monochromatic light with the wavelength of 465 nm was divided by the value of extinction of the same solution measured in monochromatic light with the wavelength Of 665 nm.

2.2.9. The Fulvic/Humic Acids Ratio

The content of fulvic acids in soil defined in % was divided by the content of humic acids expressed in %

2.3. Determination of the Saturation of the Soil Complex with Hydrogen Ions H^+

In mineral soils an air-dry soil sample with the weight of 20g, ground in a mortar, was placed in a beaker with the capacity of $100cm^3$ and treated with $40cm^3$ of water solution of NaOH. After 24 hours a potentiometric measurement of pH was made. For the subsequent measurements the solutions of NaOH with the concentrations: 0, 5, 10, 15, 20, 25, 30, 35, 40, 50 mol/m^3 were used. In organic soils the weighed portion was reduced to 5g, while the solutions of NaOH with the concentrations: 0, 50, 100, 200, 250, 300 and 400 mol/m^3 were used.

2.4. Microbiological Examinations

The total number of microbes was determined by the plate method: bacteria on agar medium with the soil extract (Bunt, Rovira 1955), macromycetes on agar medium with the glucose and yeast extract (Aaronson 1970), fungi on Czapek-Dox medium.

Bacteria producing phosphate (phosphoric bacteria) were determined on agar medium with diphosphate of phenolptalein (Band-Parker 1966) and bacteria oxidizing sulphur (sulphuric bacteria) on Wieringa medium (Wieringa 1960). The rate of ammonification and nitrification was examined by introducing to samples a substrate (asparagine) and determining after the incubation period in the temperature of 25°C the amount of products: in the case of ammonification - NH_3 by the colorimetric method with Nessler's reagent, in the case of nitrification - NO_3 by the colorimetric method with phenolosulphonic acid.

The cellulose decomposition energy was determined by the modified Petkov and Markova's method (1969) and respiration (acquisition of O_2) by the manometric method (Katznelson, Ronatt 1957).

3. Results of Investigations

The intensity of changes in humus compounds in soil is always connected with the activity of soil microorganisms which cause the decomposition of complex organic compounds into simple ones. This process depends, among other things, on external conditions and in the case discussed on the pH of simulated "acid rains". The treatment of soils with water solutions with pH ranging from 2,0 to 7,8 for the period of two years brought about the differentiation of soils (pH) from 2,5 to 2,9 of pH in mineral soils and up to 2,5 of pH in organic soils. It was reflected in the variety of soil microorganisms and, taking into consideration the dynamics of the processes going on, we should define the qualitative changes (Fig. 1,2). In mineral soils the total number of bacteria with pH 2,0 water solutions decreased by over 100% in relation to soils treated with water from an abyssal well (with pH 7,8) and by about 50% in relation to pH of the initial soils. Within the limits of pH 4,0 we can assume that the total number of bacteria is close to the value corresponding with the number of bacteria formed under the influence of conditions reasonably close to the natural state. Further increase in the pH of water solutions brings about an increase in the total number of bacteria (Fig. 1) up to pH 6,0. Sprinkling of soils with water with pH 7,8 on loamy and peat formations caused an insignificant decrease in the total number of bacteria. The above-described phenomenon occurs also in relation to sulphuric bacteria but with pH 2,0 of "acid rains", no matter what soil was examined, sulphuric bacteria were not found. On the other hand, the number of phosphoric bacteria shows a steadily growing tendency when the shift of pH increases towards the alkaline direction.

Out of the three basic groups of microorganisms, i.e. bacteria, fungi and macromycetes, a clearly increasing tendency of microorganisms correlated with the shift of pH of water solutions towards the alkaline direction is noted in the case of bacteria. The number of macromycetes depends, to a large extent, on the kind of soil, revealing an increasing tendency up to the pH of soil around 5,5-6,0. Together with the increase in pH above this value, the number of macromycetes drops. It was fungi that most strongly reacted to the pH of the soil which was the result of simulated "acid rains"; they were most numerous with the pH of water solutions around 3,0-5,0. Together with the increase in the alkalinization of water solutions the number of fungi dropped (Fig. 2).

When analysing the changes in nitrogen compunds in soil we should note their great variety. The rate of nitrification processes remained on a similar level in mineral soils, irrespectiva of the pH of soil and the pH of water solutions. In organic soils it reached much higher values and did not reveal any differentiation in relation to the pH of soils or water solutions applied (Fig. 3).

The nitrification processes in soil depended, to a large extent, on the pH of water solutions. The acidification of soil significantly inhibited the nitrification processes, whereas the alkalinization of water solutions markedly stimulated the alkalinization processes. It referred particularly to organic soils (Fig. 3). In mineral soils water solutions with pH 2,0 practically inhibited cellulose decomposition completely, whereas in the course of the increase in the pH of water solutions the intensity of cellulose decomposition increased, no matter what kind of soil was considered (Fig. 4). A similar tendency was noted in the respiration process, but pH 7,8 of water solution caused a slight decrease in the intensity of soil respiration (Fig. 4).

It follows from the present investigations that the influence of simulated acid water solutions on soil depended, to a large extent, on the kind of soil. In sandy soils the pH of soils revealed differences within the limit of 1,5 of the unit between soils treated with water solutions with pH 2,0 and soils treated with water solutions with pH 7,8. The greatest differences in the acidity of soils amounting up to 0,7 of the unit occurred when soils were treated with water solutions with pH 2,0. It referred both to sandy and dusty soils. When water solutions pH 3,0-6,0 were applied, a slight change in the pH of soils around pH in H_2O from 5,1 to 5,7 in sandy formations and pH 5,0-5,5 in dusty formations occurred. It might suggest that within these limits the negative results of soil acidification were neutralized by the buffer capacity of the soils. It was more apparent in dusty formations. When measuring pH in KCL a similar decomposition was noted but the differences were less significant.

A relatively sharp differentiation of pH in soils - from 0,4 to 0,6 of the unit also occurred when soils were treated with water solutions with pH 7,8. An analogous decomposition of pH took place in organic soils (peats) where pH, subject to the water solution applied, oscillated around 2,5 of the unit of the pH measured in H_2O and 2,3 of the unit of the pH in KCL

(Tab. 1). In this case the decopmosition was more even, i.e. together with the increase in the acidity of water solutions the degree of the acidity of peats dropped.

The influence of "acid rains" brought about a significant increase in hydrolytic acidity in soils treated with water solutions with pH 2,0 and 3,0. In relation to the control value this increase exceeded 100% in sandy and peat formations and was over 35% in dusty formations. For the water solutions applied with pH within the limits 3,0-5,0 the changes in hydroloitic acidity of soils were slight and oscillated for sandy formations around 0,3-1,5 me/g of soil, for loamy formations around 0,1-1,0 me/g of soil, for peat formations around 0,6-17,0 me/g of soil. An analogous phenomenon was noticed as in the case of pH of soils where the biggest differences in hydrolytic acidity occurred for the extreme values, i.e. for pH 2,0 and 7,8 of water solutions (Tab. 1). At the same time a considerable decrease in the sum of bases in the sorption complex was noted. In sandy and peat soils the differences for extreme values reached 250-300%, in dusty formations about 20%. The influence of the buffer capacity of silty fraction of soils was apparent.

Sandy and peat formations reveal a higher index T + S in relation to the control area. In dusty formations, on the other hand, no significant difference occurred. For all the three kinds of soils also a decrease in the sorption capacity of soils following the increase in their acidity was noted. The most striking differences occurred in sandy and peat formations reaching, for extreme values, 400% of the difference. In dusty formations the differences in the sorption capacity reached 48% among soils treated with the most acidified water solutions and water with an alkaline pH. In mineral soils the content of nitrogen oscillated around 0,077-0,112% (mean data: 0,80% - sands, 0,90% - dusty formations), while for peat soils this value oscillated around 0,823-0,955%. No dependence between the pH of water solutions and the level of nitrogen and carbon in soil was found

(Tab. 1, 2).

The analysis of the content of bitumen carried out in samples of mineral soils taken in 1987 and 1988 revealed the lack of their quantitative dependence on the pH of water solutions applied. On the other hand, with reference to organic soils a clearly increasing tendency in the content of bitumen following the increase in the acidification of water solutions was noted. The values obtained were slightly higher in the second year of the experiment.

The analyses carried out reveal a relatively consistent tendency in the occurrence of fulvic acids, i.e. their decrease in the course of increase in the capacity of water solutions. The data obtained in the first period of the present investigation (1987) as well as the results obtained from the analysis of soils originating from the second stage of investigations are indicative of the decrease in the content of fulvic acids in the course of acidification of soils. According to the kind of soil the values obtained differ by 30-300% in the first year and by about 60% in the second year of the experiment. After a two-year period of treating soils with water solutions with various pH, the content of fulvic acids in mineral formations increased on average by about 100%, while in organic soils by 16-45% (Tab. 2, 3).

The content of hymatomelanic acids markedly increased together with the increase in the acidity of water solutions applied.

The investigations showed the growing amount of brown and grey humic acids together with the increasing shift of the soil and water solutions reaction towards the alkaline direction. It refers mainly to mineral soils. The growing tendency was much stronger in the first period of investigations (Tab. 2) than in the second one (Tab. 3). With reference to organic soils no clear dependence between the pH of soil and the content of humic acids can be found.
The increasing content of humic acids is particularly apparent

in the second year of the experiment, i.e. after a longer period of the influence of the degrading factor - acid water solutions.

Together with the increase in soil alkalinization the fulvic / humic acids ration was reduced. The above-described tendency was more apparent in the first year of the experiment and it referred both to mineral and organic (peat) soils.

No regularity in the content of humins, humic carbon and the value of the $Q_{4/6}$ index of colour was found when applying water solutions with various pH.

The results obtained were very much varied which could suggest that the above-mentioned properties are more permanent and a much longer period of influence would be required in order to notice visible changes.

Discussion of Results

The content of nitrogen and humus in the soils taken as a reference point in relation to soils sprinkled with water solutions did not show any significant changes. This confirms the results of investigations obtained before by Mutsch (1986, Gögl 1986, Hay et al. 1985). In contrast with Mutsch's investigations the changes in soil reaction within the limits of pH 1,5-2,5 of the unit should be regarded as very big, taking into account a very short period of the influence of "acid rains".

Analogously to Mutsch's experiment (1986), the present investigations confirmed also the increase in the concentration of H^+ ions in sandy and peat soils by about 100%, whereas in dusty soils by about 35%.

The investigations showed great changes in the number of basic groups of soil microorganisms. It refers particularly to the number of bacteria and fungi, to a lesser degree to macromycetes. Significant changes take place in the number of the particular groups of bacteria (phosphoric and sulphuric).

These data contradict, to some extent, Öhlinger's hypothesis (1986) who, treating soils with acid rains, found their partially positive reaction to acidification. It is widely accepted that negative processes concerning the changes in inorganic compounds and biochemical processes take place in soil. It refers particularly to long-term influence of acids with a considerable concentration (Killham, Francis 1982, Ohlinger 1986, Greszta et al. 1989).

According to the kind of soils, there was a significant differentiation of chemical properties and the number of soil microorganisms proportionate to the dose of acids introduced. This process can be regarded as continual, whereas after a periodical acidification of soils (Prusinkiewicz et al.) there are clear tendencies of soils to retutn to the initial state.

Ulrich's investigations (1976) showed that under the influence of acid rains nitrification was, to a large extent, reduced or completely stopped. In the present experiment it was shown that this process takes place only when "acid rains" have pH 2,0-3,0 and are of a continual character.

The stimulation of ammonification in soil, with a simultaneous reduction of nitrification under the influence of acidification of the environment confirm the results of investigations by Crowther and Stenart (1913) who found a decrease in the content of nitrates and carbonates in soil, with a simultaneous increase of ammonia. The above-mentioned authors noted also an increase in the content of humic acids with a simultaneous decrease in the content of bases. In the present experiment it was confirmed by the results of the sorption complex investigations. Tamm's hypothesis was also confirmed; it says that the acidification of the environment has a destructive influence on soil organisms and biological processes. Strong acids exert a particularly negative influence on living organisms.

Comparing the content of bitumen in mineral soil, both in sands and in dusty formations, with the data from literature, we can note their low amount (Tiurin 1965, Terlikowski 1958, Prusinkiewicz 1970). It results from the fact that in the pot experiments the layer A_0 was neglected. Also in peats the maximum content of bitumen amounting to about 5% must be regarded as low in comparison with data given by Prusinkiewicz (1970). The investigations carried out in other scientific centres showed that there is no decrease in biological activity of soils (Bååth et al. 1980, Francis 1982, Chang, Alexander 1980).

Hay et al. (1985) in their experiment pointed to the highest content of fulvic acids in humus when water solutions with pH around 6,0 were applied; in the case of water solutions with pH 2,0 the solubility of these compound was the lowest.

In the present examinations the layers A_0 and A_{1H} were usually neglected and thus there are no data for defining the buffer properties of the humus layer of soils. In the case discussed the buffer properties can be referred only to silty fractions.

Conclusion

Because of the high buffer capacity of soils and especially of the humus layer, it must be assumed that:

1. A two-year period of investigations is too short to define fully the changes going on in the soil humus. The tendencies n the changes of humus can only be noted. The particular results of investigations must also be approached with care.

2. Under the influence of simulated "acid rains" the changes of soil reaction, reaching in mineral soils 1,5 and in peats 2,5 of the pH unit, were relatively quick. It was

justified by the increase in hydrolitic acidity by over 100% with the lowest acidification of soils.

3. With pH 2,0 and 3,0 of water solutions a significant decrease in the content of the sum of bases was noted. It refers mainly to sandy and peat formations.

4. Simulated "acid rains" considerably reduced the biological activity of soils. The total number of bacteria and phosphoric and sulphuric bacteria was also limited. The curves illustrating the content of fungi and macromycetes were more varied according to the pH of water solutions applied.

5. The acidification also brought about a reduction in the rate of nitrification, respiration and cellulose decomposition processes and a simultaneous intensification of ammonification.

6. Simulated "acid rains" did not cause any changes in the content of C and N, bitumen, humins and humic carbon in soil. The $Q_{4/6}$ index of humus colour remained unchanged, too.

7. Acid water solutions caused a decrease in the content of fulvic and brown and grey humic acids.

8. Together with the increase in soil acidification grew the content of hymatomelanic acids.

9. Water solutions with pH 7,8 (weakly alkaline) also exerted a negative influence upon the biological activity of soils through the reduction of both the number of microorganisms and the rate of biochemical processes.

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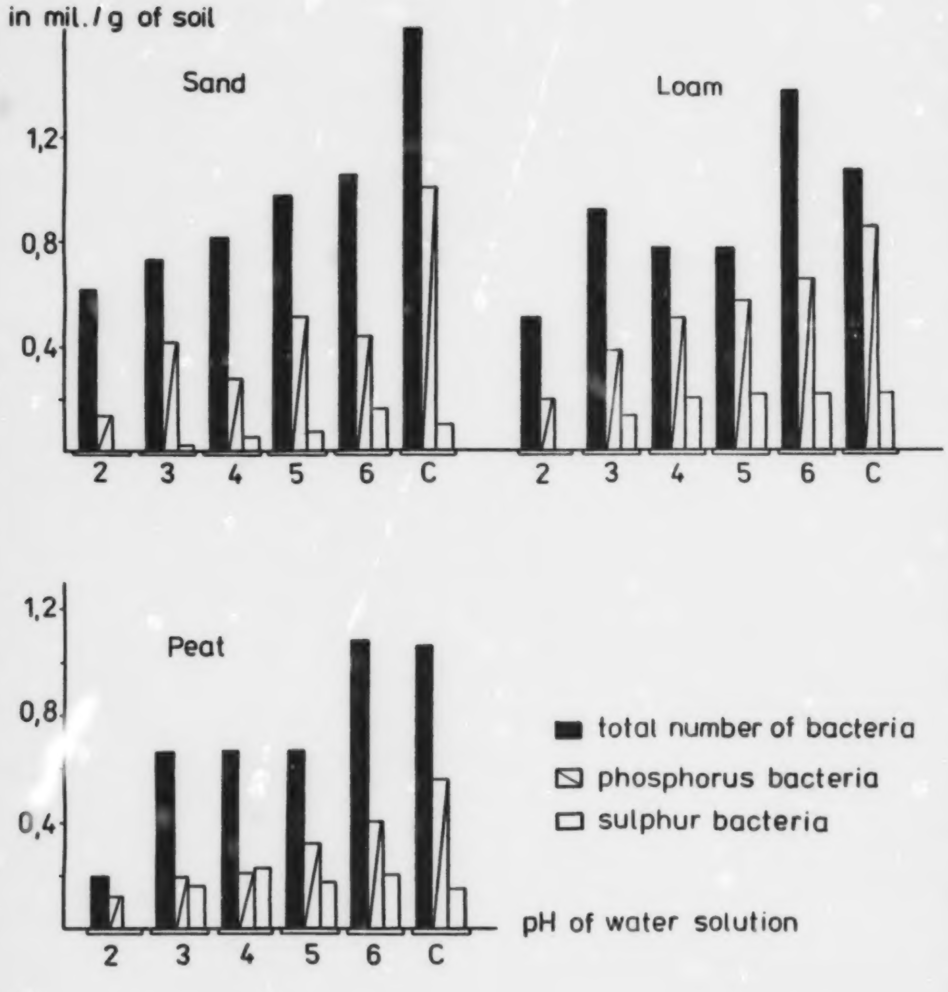
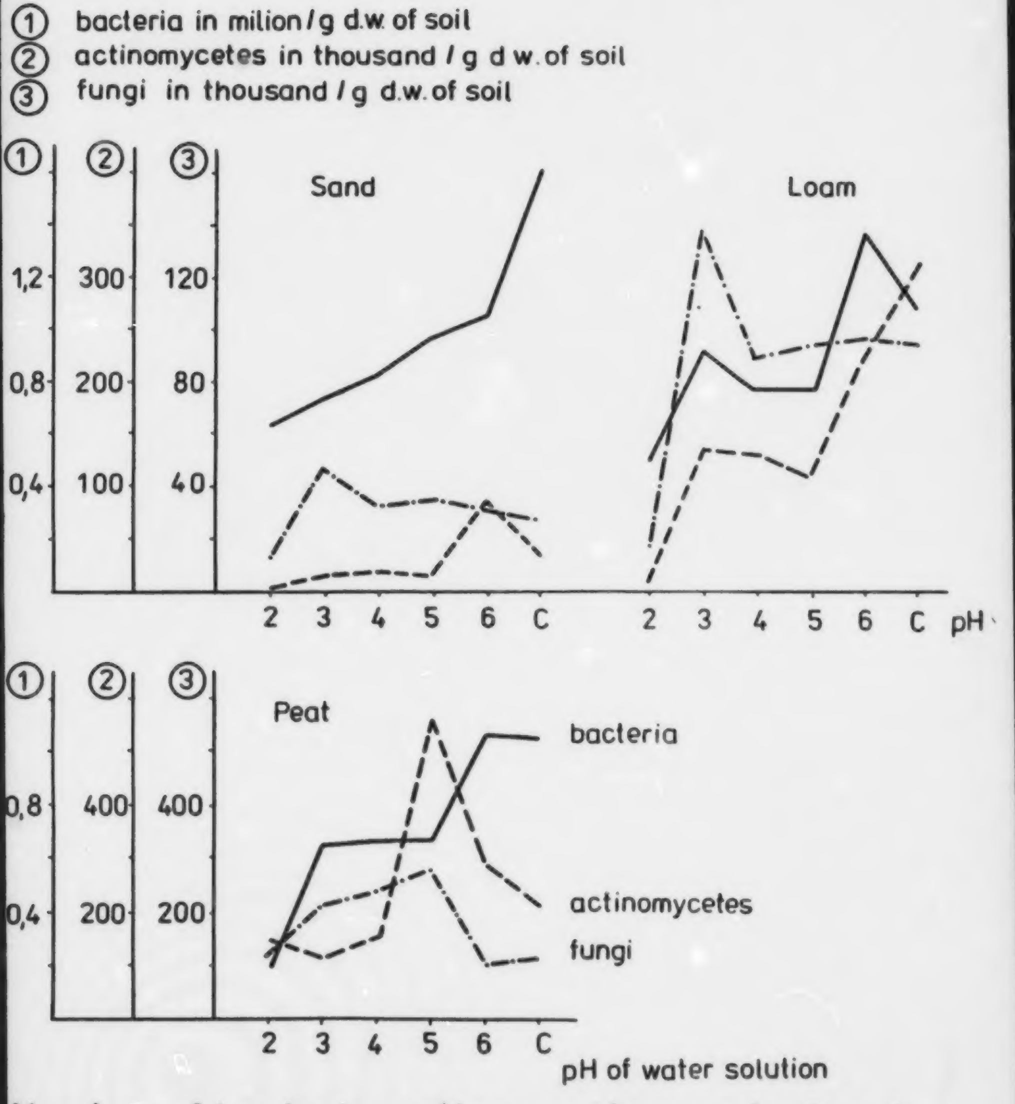
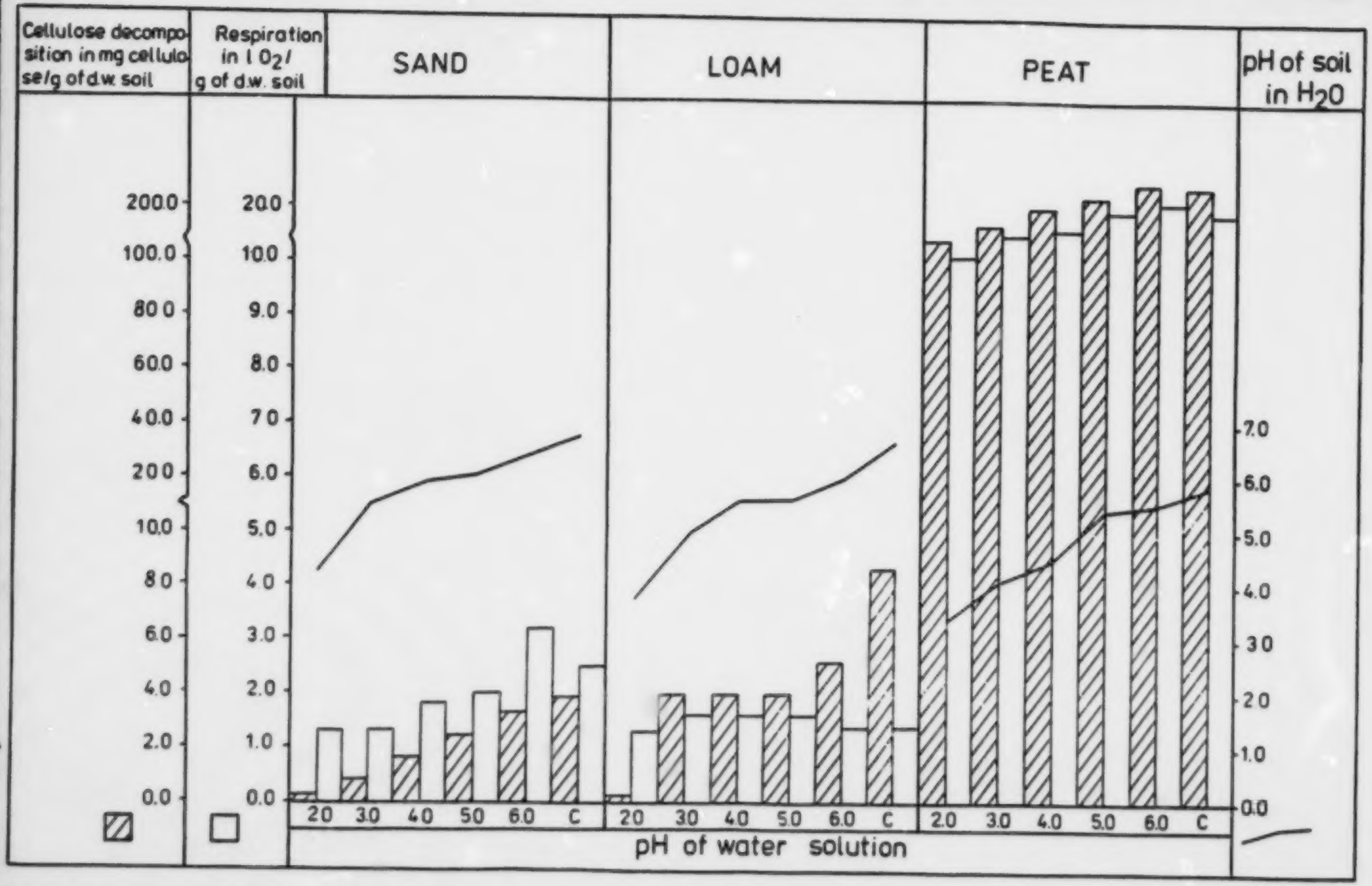


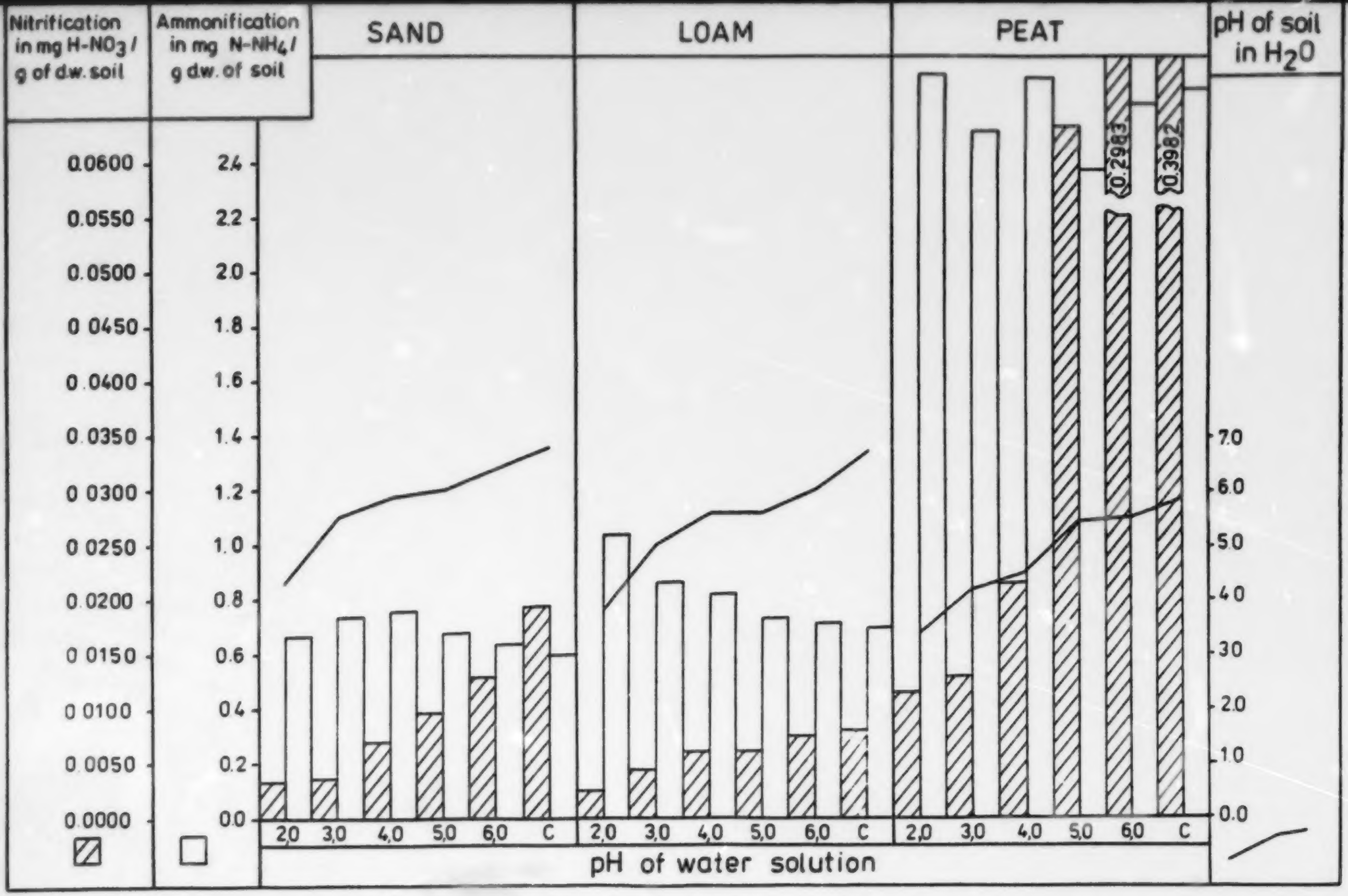
Number of bacteria in soil according to pH of water solution.



Number of bacteria, actinomycetes and fungi according to pH of water solution.



Cellulose decomposition and soil respiration according to pH of simulated „ acid rains."



Effect of ammonification and nitrification processes in soil according to pH of simulated „acid rains."

. Tab. 1. Chemical properties of soils

pH of water solution	pH		C in %	Organic substance in %	Sorption complex			
	in H_2O	in KCl			Y	S	T Y+S	V%
SANDY FORMATIONS								
2,0	4,4	4,2	1,21	2,09	10,5	1,8	12,3	14,6
3,0	5,1	4,7	1,37	2,49	7,5	1,7	9,2	18,5
4,0	5,2	4,7	0,99	1,37	6,2	0,9	7,1	12,7
5,0	5,2	4,9	0,80	1,37	6,5	1,9	8,9	22,6
6,0	5,7	5,5	1,30	2,21	4,9	3,6	8,5	42,4
7,8	6,1	5,6	1,13	2,29	4,3	5,3	9,6	55,2
DUSTY FORMATIONS								
2,0	4,3	4,1	1,14	1,96	8,3	5,7	14.0	40,7
3,0	5,0	4,7	1,20	2,07	6,5	5,4	11,9	45,4
4,0	5,4	4,6	1,22	2,10	6,1	6,4	12,5	51,2
5,0	5,4	4,9	1,26	2,17	6,2	6,5	12,7	51,2
6,0	5,5	4,9	1,06	1,82	6,4	6,5	12,9	50,4
7,8	6,1	5,3	1,16	1,99	5,4	7,6	13.0	58,5
PEAT								
2,0	3,3	3,1	32,68	63,5	104,3	14,8	119,1	12,4
3,0	3,7	3,4	50,00	69,0	78,6	36,5	115,1	31,7
4,0	3,8	3,3	37,17	62,4	71,3	39,0	110,3	35,4
5,0	3,9	3,6	36,65	67,5	70,7	35,8	106,5	33,6
6,0	4,2	3,4	38,85	68,7	53,7	54,1	107,8	50,2
7,8	5,8	5,4	36,10	60,9	53,6	40,7	94,3	43,2

Tab. 2. Fraction analysis of the humus of 3 kinds of soil treated with simulated "acid rains" for the period of 1 year.

Kind of soil	pH of simulated "acid rains"	Content in soil								Ratio values	
		C org. in %	Humus in %	Bitumen in %	Fulvic acids in %	Humic acids			Humins and humic carbon	Fulvic/humic acids ratio	$Q_{4/6}$ index of colour
						Total in %	Brown in %	Grey in %			
Sand	2,0	0,25	0,436	0,14	0,076	0,065	0,044	0,021	0,159	1,17	4,12
"	3,0	0,26	0,453	0,15	0,096	0,074	0,041	0,033	0,133	1,30	3,74
"	4,0	0,26	0,457	0,19	0,091	0,076	0,042	0,034	0,130	1,20	3,78
"	5,0	0,29	0,424	0,18	0,094	0,069	0,031	0,038	0,163	1,36	3,46
"	6,0	0,27	0,473	0,12	0,120	0,087	0,030	0,057	0,166	1,79	3,79
"	7,8	0,27	0,476	0,15	0,091	0,087	0,052	0,035	0,166	1,36	3,47
Loam	2,0	0,26	0,451	0,04	0,048	0,091	0,029	0,062	0,272	0,53	3,97
"	3,0	0,33	0,566	0,07	0,112	0,170	0,071	0,099	0,214	0,66	3,28
"	4,0	0,37	0,636	0,08	0,136	0,146	0,061	0,085	0,274	0,93	3,28
"	5,0	0,35	0,603	0,14	0,108	0,129	0,036	0,093	0,226	0,84	2,91
"	6,0	0,28	0,477	0,15	0,162	0,144	0,036	0,108	0,221	1,22	2,77
"	7,8	0,30	0,512	0,15	0,100	0,172	0,043	0,129	0,280	0,58	2,82
Peat	2,0	32,68	63,50	3,78	1,147	1,925	0,183	1,742	57,741	0,60	3,32
"	3,0	40,00	69,00	3,52	1,578	1,675	0,140	1,535	61,430	0,94	3,21
"	4,0	37,17	62,40	2,66	1,578	1,830	0,403	1,427	61,342	0,86	2,71
"	5,0	36,65	67,50	3,38	1,472	2,297	0,459	1,838	60,352	0,78	2,63
"	6,0	38,85	68,70	2,72	1,789	1,630	0,238	1,392	64,370	0,98	2,42
"	7,8	36,10	60,90	2,52	1,544	1,794	0,359	1,435	55,042	0,86	2,64

Tab. 3. Fraction analysis of the humus of 3 kinds of soil terated with simulated "acid rains" for the period of 2 years

Kind of soil	pH of simulated "acid rains"	Content C-total in soil in %	Humus content in soil in %	Content of fraction of the humus in soil							Ratio values	
				Bitumen in %	Fulvic acids in %	Hymatomelanic acids in %	Humic acids /total/ in %	Humic brown acids in %	Humic gray acids in %	Humins and humic carbon in %	Fulvic/humic acids ratio in %	$Q_{4/6}$ index of colour
Sand	2,0	0,37	0,64	0,08	0,204	0,028	0,145	0,061	0,84	0,143	2,10	3,00
"	3,0	0,34	0,59	0,06	0,226	0,016	0,155	0,048	0,107	0,143	1,46	2,83
"	4,0	0,36	0,63	0,11	0,269	0,019	0,163	0,049	0,114	0,169	1,65	2,32
"	5,0	0,32	0,55	0,07	0,258	0,014	0,198	0,071	0,127	0,111	1,30	3,07
"	6,0	0,38	0,66	0,10	0,223	0,016	0,172	0,075	0,097	0,169	1,30	3,14
"	7,8	0,37	0,65	0,09	0,238	0,013	0,207	0,074	0,133	0,102	1,15	3,07
Loam	2,0	0,58	1,00	0,12	0,186	0,014	0,115	0,023	0,092	0,481	1,57	2,60
"	3,0	0,59	1,02	0,11	0,211	0,010	0,139	0,039	0,100	0,570	1,52	2,53
"	4,0	0,63	1,09	0,14	0,203	0,008	0,152	0,042	0,110	0,598	1,34	2,91
"	5,0	0,55	0,35	0,18	0,234	0,006	0,212	0,070	0,142	0,518	1,10	3,00
"	6,0	0,62	1,07	0,12	0,280	0,005	0,230	0,076	0,154	0,545	1,22	2,88
"	7,8	0,58	1,00	0,10	0,219	0,006	0,216	0,078	0,138	0,449	1,01	3,66
Peat	2,0	34,76	59,93	4,93	1,700	1,191	3,396	0,115	2,581	49,233	0,41	2,69
"	3,0	36,12	62,27	3,42	1,780	1,161	2,668	0,160	2,508	53,241	0,67	2,16
"	4,0	31,09	54,94	3,07	1,900	1,088	2,668	0,267	2,401	44,408	0,71	2,33
"	5,0	38,17	65,80	2,95	2,530	1,441	2,911	0,378	2,533	56,008	0,87	2,41
"	6,0	34,69	59,71	2,69	2,468	1,311	2,749	0,275	2,474	46,692	0,89	2,34
"	7,8	36,73	63,33	2,97	2,624	1,233	2,567	0,259	2,328	51,914	1,01	2,32

Tab. 4. The value of pH of soil solution according to the saturation of the soil complex with the sodium base.

No	Medium	Soil mass g	Volume of the solution cm^3	Concentration of the solution mol NaOH/m^3	pH of the soil solution after 24 hours of treating the soil with water solution of NaOH for soils remaining under the influence of acid rains with pH					Cpntrol /rain without aci contamination/
					2,0	3,0	4,0	5,0	6,0	7,8
1	Sand	10	20	0	4,16	5,53	5,54	5,60	6,05	6,60
2	"	10	20	5	4,77	7,11	7,12	7,47	7,86	8,40
3	"	10	20	10	6,87	8,02	8,02	8,25	8,46	9,11
4	"	10	20	15	7,91	8,36	8,37	8,52	8,54	9,34
5	"	10	20	20	8,42	8,54	8,53	8,67	8,70	9,50
6	"	10	20	25	8,63	8,65	8,66	8,70	8,72	9,54
7	"	10	20	30	8,68	8,70	8,71	8,72	8,73	9,56
8	"	10	20	35	8,76	8,78	8,76	8,78	8,79	9,57
9	"	10	20	40	8,79	8,80	8,81	8,83	8,84	9,58
10	"	10	20	50	8,80	8,84	8,85	8,87	8,90	9,60
11	Loam	10	20	0	4,37	4,92	5,27	5,30	5,64	5,37
12	"	10	20	5	4,60	5,25	5,71	5,73	6,93	6,05
13	"	10	20	10	4,93	5,74	6,40	6,43	7,46	6,91
14	"	10	20	15	5,23	6,33	7,22	7,25	8,17	7,60
15	"	10	20	20	5,67	7,04	8,06	8,08	8,64	6,22
16	"	10	20	25	6,82	7,61	8,53	8,56	9,00	8,63
17	"	10	20	30	6,96	8,08	8,72	8,76	9,18	8,89
18	"	10	20	35	7,41	8,34	8,84	8,87	9,27	9,02
19	"	10	20	40	7,65	8,58	9,00	9,02	9,34	9,14
20	"	10	20	50	8,24	8,81	9,08	9,11	9,43	9,28
21	Peat	5	30	0	3,72	3,82	4,18	5,50	4,33	4,52
22	"	5	30	50	4,60	4,92	6,21	8,47	5,49	5,50
23	"	5	30	100	6,54	6,75	7,42	9,38	7,14	7,16
24	"	5	30	150	7,79	8,01	8,27	9,88	8,35	8,34
25	"	5	30	200	8,46	8,61	8,85	9,96	9,01	9,05
26	"	5	30	250	8,90	9,01	9,22	10,04	9,32	9,35
27	"	5	30	300	9,21	9,28	9,40	10,07	9,53	9,58
28	"	5	30	400	9,61	9,70	9,78	10,12	9,98	10,01

Effects of Air Pollution on Soil and Nutrient Uptake in Coniferous Forest Ecosystems

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FDC: 425.1 : 425.3: 181.45: 181.34: 174.7

Summary

The observation that i) the so called new type of forest damages in coniferous forest ecosystems are frequently associated with acute nutritional disturbances, ii) these disorders predominantly concerning Mg, K and Ca have developed gradually on specific sites but within a relatively short time period and iii) a reduction in the availability of these nutrient ions in the rooted solum has been documented for approximately the same time frame, soil mediated pathways have been found to at least partly explain these recent forest damages. Acid deposition related to the input of H^+, SO_4^{2-} and NO_3^- may attribute to accelerated soil acidification causing enhanced losses of alkaline nutrient ions such as Mg, Ca and K. High Al^{3+} soil concentrations have been measured but it appears that Al toxicity is not a relevant mechanism in the cause of the decline of coniferous tree species under present field conditions. However, there is no doubt that high Al^{3+} contents effect Mg, Ca and perhaps also K uptake via roots (Mg/Al, Ca/Al antagonism). Increasing deposition of NH_4^+ - a much more favourable N source for nutrition of conifers than NO_3 - may enhance soil and - more importantly - rhizosphere acidification, induce nutrient imbalances in soil and trees and cause mycorrhiza damages. However, the later effect is controversial. It also appears that heavy metal contamination of forest soils is not a general cause of the mycorrhiza, root and/or above ground tree damages. Owing to the accumulation in the organic matter of the forest floor they nevertheless represent a potential hazard for the future and may presently adversely influence soil micro-organisms. Furthermore, effects of air pollutants and/or acid precipitation directly to the crowns of coniferous trees, e. g. provoking increased nutrient leaching also affect the soil by enhancing rhizosphere acidification and/or nutrient imbalances and/or reduced cation or anion uptake. There is growing evidence that one-sided counteracting measures such as drastically decreased emission of dust and - more recently - of SO_2 - while emission of e. g. NO_x and NH_3 are still increasing - may attribute to this phenomenon and/or bring about other negative effects. For example, insufficient S supply has been indicated for the first time in spruce and beech on high elevation sites in the cristalline Black Forest. Therefore all measures aiming at reducing the forest damages must be based upon a profound analysis of the complete ecosystem. When considering only parts of the system for indirect (e. g. reduction of emissions) or direct (liming/fertilization) measures, other mechanisms could be initiated that negatively affect other compartments of the forest ecosystem including the hydrosphere.

LONGTERM EFFECTS OF ATMOSPHERIC POLLUTANTS ON NUTRITION OF NORWAY SPRUCE AND REVITALIZATION OF DECLINING STANDS IN AUSTRIA

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FDC: 425.1: 425.3: 181.32: 237.4: 174.7 Picea abies Karst.

ABSTRACT

Needle loss and needle yellowing are wide spread phenomena in declining montane forests of Central Europe. Input of atmospheric pollutants is considered to be a main stressor responsible for these symptoms. There is, however, high spatial variability of decline symptoms. Deposition measurements during the past five years on three sites with differing aspect and elevation in the "Bohemian Forest" of Austria, close to the Czech and Bavarian border (Schöneben 1-3), have shown strong variation of deposition patterns. The west exposed slope and the hilltop receive 30 percent more sulfur and nitrogen with throughfall than the east exposed site, while deposition rates in the open do not differ significantly. Persistently high nitrate concentrations in the soil solution of the west exposed site indicate nitrogen saturation of the system. The least vigorous trees however are found at the ridge-site, a former pasture with soils of extremely low base saturation. This shows, that absolute load of air pollutants alone is not determining the condition of the forest stands. In order to investigate predisposing stress factors which influence the vigor of Norway spruce stands, soil and needle analysis, and a detailed survey of site conditions on fifty sites were used. Regression analysis and multivariate procedures have been used to estimate factors determining tree nutrition and vigor. The survey confirms that the least vigorous trees can be found on west exposed slopes in higher elevation. The soils at these sites are extremely low in base saturation. Historical land use, such as litter raking, grazing and burning of biomass for potash led to nutrient depletion. Increasing deposition of atmospheric nitrogen during the last decades alleviates nitrogen stress. The ratios of nitrogen to calcium and magnesium in needles are very wide on these sites and indicate nitrogen induced nutritional imbalance. Available rooting space and water status of the site are further main factors for tree nutrition. The nutritional status of trees and soil parameters, combined with known deposition patterns are used to define critical site conditions and critical loads for atmospheric pollutants. To test the possibility for improving nutrition and tree vitality, fertilization experiments were established 1987. Fertilization with a combination of organic fertilizer and magnesite brought encouraging results within a time span of three years. Fertilization improved tree vigor and nutritional status significantly and resulted in a significant response of growth and seed yield. Thus the objective of raising the nutritional status of the system to a higher level seems to be practicable. The effects of such measures on groundwater quality are not clear at present. An increased nitrate content of soil solution in the second year after fertilization shows that trees were not able to use additional nitrogen supplied with the fertilizer.

CHANGES IN SOIL CHEMISTRY AND MINERALOGY BY ACID RAIN

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FDC: 425.3: 114.32: 114.25/.26

SUMMARY

The goal of the present study was a qualitative and quantitative determination of chemical and mineralogical changes in soils due to acid atmospheric immissions.

In the Vienna forest soil samples were taken at 4 depths (0-5 cm, 5-10 cm, 10-20 cm, 20-30 cm) in the stemflow area (S) of beech trees (fagus sylvatica), strongly influenced by acid atmospheric immissions (pH 2,8-3,0) and in the reference (R) areas between trees, without significant external influence (pH 5,0-6,0).

The results show that intensive weathering processes took place in the contaminated soils, which show higher clay and silt content and smaller aggregates, as well as clay alluviation. Moreover, in the top soil of the highly immitted stemflow area higher contents of Ct, St, Nt and of the heavy metals Pb, Zn and Cu could be observed, accompanied by extreme low base saturation (expecially of Ca and Mg) and high Al-saturation (50-80% of the CEC). These data were confirmed by analysis of the water saturation extract. Moreover, in the contaminated top soil of the stemflow area high amounts of Fe-oxides were found, whereas no "secondary" Al-chlorites (due to their instability at pH-values 4,0) could be traced.

The desilification process which took place at the same time could be shown through total element analysis. In the clay fraction strong weathering led to a loss of layer charge and to the genesis of highly expandable three-layer -silicates which could be determined by the use of n-alkylammonium-chloride technics and other chemical treatments.

Keywords: stemflow, weathering, acidification, desilification

SCOTS PINE STANDS RECONSTRUCTION POSSIBILITIES IN THE UPPER SILESIA INDUSTRIAL REGION

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SUMMARY

Reconstruction of tree stands resolves itself into selection of suitable tree species, making use of various ways of tree stand reconstruction, consisting in use of various forms of cutting measures, and application of various agro- and phytomelioration procedures. A principle is adopted in Poland, that in dependence on site conditions a set of tree species as broad as possible is used in a mosaic pattern /clumps and clusters of trees/. Two main ways of tree stand reconstruction were discussed: complete reconstruction with the use of clearcuttings and partial reconstruction with the use of partial cuttings. A principle was adopted at the proceeding of tree stand reconstruction, that the dying coniferous tree stands should be kept on standing as long as possible. Partial reconstruction showed many good points when compared to the total reconstruction. A valuation of complete soil tillage was also accomplished.

Keywords: Silviculture, reconstruction

INTRODUCTION

A negative influence of the industry on the forests in Poland can be traced best on the example of the Upper Silesia Industrial Region - the oldest and the greatest urban - industrial agglomeration in the country. The first damage in those forests consisted in the intensification of cutting of hardwood tree stands, providing the metallurgy with charcoal.

A rapid development of pit-coal mining and blast-furnace metallurgy caused the decrease of request for charcoal but at the same time it caused an increase of the demand for pit-prop wood, mainly of pine and spruce. At the end of 18th century a renowed boom in lead and silver mining and metallurgy was also noted. At the same time a demand for coniferous pulpwood for pulp and paper industry being in a dynamic development increased abruptly. These phenomena caused, that from the middle of the 19th century monocultures of coniferous species in mass were planted, and that caused a disastrous decrease of the share of broadleaved species in the forests of Upper Silesia. During less than two centuries the species composition of tree stands on the area changed in that way. The place of mixed and broadleaved tree stands were then taken out by coniferous monocultures, mainly of Scots pine /Pinus silvestris L./ and Norway spruce /Picea abies L./, and that occurred on industrial and economic reasons.

The first damage by industrial imissions in Silesian forests appeared as early as at the end of 19th century. Signals on pine and spruce tree stand decline were also noted during the inter-war period /Łuczkiewicz 1922/. An especial worsening of forest health state occurred after the 2nd World War as a result of rapid development of industry.

During the past decades scientists and practice men were posed in front of questions new by their quality, especially in the field of forest management in industrial regions. Restructuring species composition of tree stands, consisting in replacement of dying coniferous monocultures by forest associations composed of species.sensitive to air pollution less than fir /Abies alba Mill./, Norway spruce or Scots pine, became a main task in the forest management.

Reconstruction of tree stands does not resolve the problem of forest damage caused by industrial imissions, but it makes the question less severe. Tree species fully resistant against industrial air pollution do not exist after all.

The first attempts to restructure tree stands in Poland were done in the beginning of fifties in the central part of the Upper Silesia Industrial Region. The reconstruction of tree stands on an economic scale started in 1958 on the area of Katowice voivodship in 1970 - 1987 about 51 thous. ha of tree stands were rebuilt in Poland, including about 40 thous. ha on the area of the Regional Board of State Forests in Katowice. The area of tree stands still needing reconstruction in the country amounts to about 45 thous. ha in the next 20 years, including about 35 thous. ha in the Katowice Regional Board of State Forests /Ochrona Środowiska : Gospodarka Wodna 1988/.

The question of reconstruction of tree stands damaged by imissions resolves itself mainly into :
- selection of tree species,
- making use of the most favourable procedures of reconstruction, consisting in utilization of various forms of cutting, and
- application of various agro- and phytomelioration measures.

TREE SPECIES FOR TREE STAND RECONSTRUCTION

The replacement of coniferous species by species less sensitive to imissions, and broadleaved species are most frequently among them, is not easy in the course of tree stand reconstruction, for hardwood species have most frequently greater needs in relation to the soil fertility and water than do pine or spruce. The poorer are ground-soil conditions and higher the degree of air pollution, the more difficult becomes the performance of reconstruction.

A principle was adopted at carrying out the reconstruction of tree stands, that a set of tree species as broad as possible should be used for regeneration in dependence on ecological conditions, in a mosaic pattern /clumps and clusters of different trees intermingled;/Latocha 1975/. Caution regards speak for introduction at least several species to cultures, since it is difficult to predict how far might ecological conditions change in the future and how will individual tree species in older age react to their change. Planting of monocultures brings a threat of fungi diseases and insect pest becoming active.

The nature by itself provided first indications concerning tree species that should be planted in the place of dying coniferous tree stands in the Upper Silesia Industrial Region. A regeneration of aspen /Populus tremula L./, birch /Betula sp./ and oak /Quercus sp./ began to appear in blank spaces and gaps on more fertile sites.

As early as in 1958 the Regional Board of State Forests in Katowice pointed out to the necessity to limit the share of Scots pine /Pinus silvestris L./ and Norway spruce /Picea abies L./ in species composition of cultures. Provisional instructions on afforestation in the area of the central part of the Upper Silesia Industrial Region were issued in 1953 - 1955 on the ground of field experience and literature data. A decrease of the share of Scots pine and Norway spruce in planted cultures in favour of birch /Betula sp./, pedunculate oak /Quercus robur L./, eastern red oak /Quercus rubra L./, limetree /Tilia sp./, and beech /Fagus sp. / was recommended there by then.

In 1966 a team of experts from the Regional Board of State Forests in Katowice, the Bureau of Forest Management and Forest Geodesy, and the Forest Research Institute worked out a draft of management of forests situated within the reach of industrial influence. That draft indicated, among others, frames for species composition of cultures for individual categories of sites in dependence on the zone of threat by imissions, allowing mainly for native species of trees and shrubs /Techno-silvicultural principles 1969/. Instructions for species composition were modified in the next edition of silvicultural principles /1979/, basing mainly on field observations.

The following species of hardwood species : pedunculate oak, sessile oak,/Quercus sessilis Ehrh./, eastern red oak, aspen and other poplars /Populus sp. /, common birch /Betula pendula Roth./, pubescent birch /Betula pubescens Ehrh./, beech /Fagus silvatica L./, hornbeam /Carpinus betulus L./, maples /Acer sp. /, alder /Alnus sp. /, and black locust /Robinia pseudacacia L./ are mainly introduced at the tree stand reconstruction.

An average species composition of cultures on clearcutting areas of the Upper Silesia Industrial Region on coniferous forest sites represented /in per cents/ : birch -20, eastern red oak -20, pedunculate oak -15, European larch /Larix decidua Mill./ -8, Austrian pine /Pinus nigra Arn./ -8, and Scots pine -4. The share of phytomelioration species : common alder /Alnus glutinosa L./ and grey alder /Alnus incana L./ was about 14 per cent. The rest of 11 per cent comprised admixture species, such as : beech, common maple Acer platanoides L./, sycamore /Acer pseudoplatanus L./, small leaved lime /Tilia cordata Mill./, European ash /Fraxinus excelsior L./, aspen, black locust, European white elm /Ulmus laevis Pall./ and hornbeam /Carpinus betulus L./.

Aspen, and next common birch, common alder, European larch, eastern red oak, and pedunculate oak show the greatest dynamics of height increase on open surfaces when being young. Common maple, sycamore, beech and limetree grow a bit more slowly, while eastern white pine /Pinus strobus L./ and Austrian pine are the slowest.

It can be stated on the ground of to - date experiments and observations on the development of trees and shrubs in various site conditions /Hawryś 1984, Hawryś et al. 1977 and 1980, Latocha 1975, Latocha et al. 1980, Zajączkowski and Szeremetti 1978/, that the following species showed the best usefulness for forest regeneration in industrial regions of Poland : Austrian pine, eastern white pine, European larch, Japanese larch /Larix leptolepis Gord./, pedunculate oak, sessile oak, eastern red oak, common birch, red beech, European ash, rowan tree /Sorbus aucuparia L./, grey alder, common alder, and black cherry /Padus serotina Ehrh./.

Northern white cedar /Thuja occidentalis L./ and eastern hemlock /Tsuga canadensis Carr./, from among other species introduced on more fertile sites,may find use in conditions of medium threat by imissions. To-date observations on Douglas fir /Pseudotsuga menziesii Mirb./ do not predict possibilities for broader introduction of this species on clearcut areas in the Upper Silesia Industrial Region.

One should strive, that the production of plantings of basic species were based on local seed crop stands.

METHODS OF TREE STAND RECONSTRUCTION

We single out two methods of tree stand reconstruction : either total one at application of clearcuttings or partial another with use of partial and group cuttings.

A principle was adopted of keeping the existing coniferous stands on standing as long as possible. Economic, climatic and conservational regards speak for that. One should in addition pay attention to the fact, that partial cutting makes more favourable conditions for the growth in the initial period for the majority of native tree species. The introduction of young generation with simultaneous maintaining of older tree stands makes possible a setting of more productive two-floor stands, with the upper floor composed of pine, and the down floor - of oaks, maples and beech.

The negative middle-aged stands are removed by administering of clearcutting 10 - 30 m wide strips, where broadleaved cultures with the admixture of larch and Austrian pine are introduced. Curtains composed of Scots pine, to be removed after some years /in the second circulation period/ are left between clearcut strips.

Examinations and observations carried out showed many advantages of carrying out the reconstruction of tree stands in the partial manner.

The cover, even composed of strongly thinned old growth of Scots pine, protects the species sensitive to temperature drops below 0°C, such as beech and eastern red oak, against ground frosts in spring periods.

Zwoliński /Latocha et al. 1980/ found, that partial cutting influences favourably the higher microbiological activity of soils /in 0-5 cm level/ when compared to the clear-cutting.

The upper 20 cm soil layer on spaces under the cover contains more humus and total nitrogen than on clearcuttings.

Kowalski /1979/ considers the shelter-wood felling as the most convenient for tree stand reconstruction in the light of investigations on the share of parasitic fungi in the decline of trees.

The investigations by Chłodny /Latocha et al. 1980 /proved, that in the conditions of shelter-wood felling the density of phytophagous insects and traces of their feeding is lesser than at the clearcutting. At the same time this author found useful arthropods, especially nonspecialized predators such as spiders and ants far more plenty under the cover of old-growth than on clearcuttings.

The shelter of pine old growth forest influences distinctivel hamperingly the take-up of some heavy metal elements from the air, such as zinc and manganese, by the assimilation apparatus of young trees. One may then speak about clear protective role of the canopy in gathering of particles of those two elements in comparison to the open space of clearcutting/Latocha;Biedroń 1983/. One may suppose, that particles of heavy metals settle in old-growth crowns.

Schneider and Ordon /1978/ consider, that it would be most favourable to carry out the reconstruction in pine tree stands on narrow strips going perpendicularly to the direction of the move of air pollution.

Taking into account the results of investigations and observations mentioned above one may state that timber forest and ripening stands /of IV and higher age classes/, thinned and blanked im the result of removing of dying trees, with a factor of crop density degree being 0,5 or lesser, should first of all be indicated for settling of under-canopy cultures.

The reconstruction of tree stands situated in both the 1st zone of/ little / threat by imissions and in the 2nd zone of /moderate/ threat on all forest sites should first of all be performed in the partial form. The total reconstruction should be limited to tree stands situated in the 3rd zone of /great/ threat by imissions, on poor coniferous forest sites in particular.

From among various forms of clearcutting the clearcutting 15 - 30 m wide strips are most worthy to recommend, at the reconstruction of younger and middle age classes in particular. This form sets the most favourable conditions for the growth in the initial period for such species as larch, Austrian pine and eastern white pine. The curtains of coniferous forest of the same width as of stripes are left between cut strips, that have to be removed and reforested after 7 - 10 years at the second circulation period.

FULL TILLAGE OF THE SOIL

The investigations and observations carried out in both cultures and thickets being an effect of tree stand reconstruction on the area of the Upper Silesia Industrial Region showed, that full tillage on sandy soil /50-70 cm in depth/ promotes growth and development of nearly all tree species in their juvenile period, when compared to partial methods of soil preparation / in furrows, discs, etc./. Yuong trees on full tillage areas are characterized by a greater surface of assimilation apparatus. Broadleaved plantings especially outstand with their great leaves and dense branching.

The percentage of losses on tillage areas is 5.5 times less than on discs. After seven years of growth in culture the plantings of individual species on full tillage reached the height by about 29-55 per cent greater than planted in hollows. Better survival and growth of cultures on full tillage areas is a result of the improvement of some physical properties of soils after the ploughing /better humidity, shallower drying during droughts/ and as well as of lesser covering of soils by weeds in first years after the tillage.The air layer nearby ploughed soil is distinctively warmer as the result of lesser heat radiation from soil surface.

The full tillage causes the decrease of the acidity of the soil in the ploughed layer, and this is advantageous fact, because the species introduced in the place of Scots pine have usually greater needs in relation to acid reaction of soils. However, the decrease of the content of nitrogen, potassium and magnesium in the ploughed soil layer is an unfavourable phenomenon. Lesser pH index of the soil and a lesser content of some macrocomponents, as well are caused by the transfer of a part of acid litter and upper fertile soil layers rich in humus outside the area of cultures during stump extraction preceding full ploughing.

The full tillage of soil lessens the lead content by 2/3 and zinc by 1/3 in the ploughed soil in comparison to the content of those metals there, where partial preparation of soil was done. This matter of fact is influenced by the removing, before the full ploughing, of a part of litter and surface soil layers /at stump extraction / that reveal strong properties of accumulation of heavy metals coming from imissions /Biedroń and Latocha 1979/.

Zwoliński /Latocha et al. 1980/ found, that full ploughing influences favourably microbiological activity of soils /in 0 - 5 cm level/ in comparison to soil preparation in hollows.

The results of phytopathological investigations speak also in favour of full soil tillage. Both in cultures and in thickets a lesser Infectation of young trees by root-rot fungus /Heterobasidion annosum Bref./ is observed on areas after full soil preparation with stump extraction, than where partial preparation of soil was administered, with leaving stumps of old-aged trees of Scots pine /Kowalski 1979/. The full soil tillage makes also the conditions more favourable for better development of tree root systems/Latocha 1986 /.

Taking into account the outcome of investigations mentioned above it is recommended to make use of full ploughing /50 - 70 cm in depth/ first of all on sandy soils of coniferous forest sites in the 3rd zone of /intense/ threat to forests by imissions. Full ploughing should not be used on soils with a high soil water table, because a bogging of the area may succeed.

In dozen or so-year old thickets planted on full tillage areas a decrease of height growth dynamics in birch and eastern red oak is observed mineral topdressing of such areas should be carried out in such cases basing on soil analyses performed.

Liming measure is also used for counteracting degradation and toxicity of soils. It should be stressed, that possibilities of counteracting degradation of forest ecosystems caused by imissions are limited in the way of tree stand reconstruction, liming and mineral fertilization.

It should be stressed at the end that reconstruction of tree stands in industrial regions does not solve the problem of damage to forest ecosystems by imissions, and it allows only for their partial mitigation. A reduction of industrial emissions in all European countries is necessary for futher restraining of impairment of forest sites.

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RESULTS AND NEW OBJECTIVES IN RESTORING THE FOREST DAMAGED BY AIR POLLUTION IN BOHEMIAN MOUNTAINS

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SUMMARY

Based on thirty years´experience and scientific findings on the restoration of destructed forest ecosystems in the Bohemian part of the Ore Mountains (Erzgebirge) a strategy of forestry has been established for other mountain areas damaged by various types of air pollution with regeneration procedures being the most effective method. The introduction of the tolerant conifer species is desirable and reasonable to ensure the specific roles of the forest. The afforestation methods have to be in accordance with this strategy.

Keywords: Heavily polluted regions, mountain forest silviculture, ecology of succession, alpine timber line, tolerant tree species, substitute forest stands, forest soil treatment, regeneration, afforestation.

INTRODUCTION

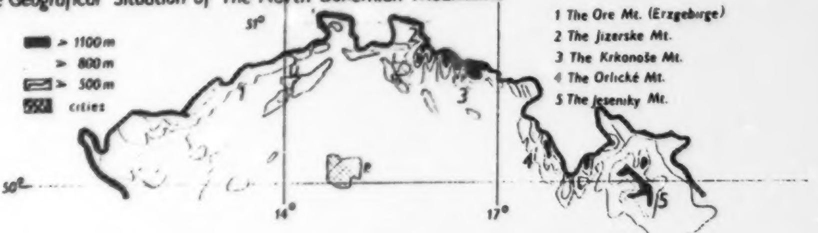
The Ore Mountains and other Mountains in the Nothern part of Bohemia are of European priority due to the areal extent and intensity of damage to the subalpine spruce forest ecosystem. In the course of the last thirty years forests have been totally destructed on the area of about thirty thousand hectars. Even though it has been afforestated with a great effort, the forests have lost their productive and other ecological functions. Since the end of 70s´the spruce forests have been newly, progressively and strongly damaged also in other North Bohemian Mountains. The restoration of the upper parts is extremely difficult for the unfavourable immission-ecological conditions. Since the mountain forest is going to get into a similar situation in the temperate zone it will be useful to summerize the long lasting information on the restoration of the Ore Mountains. On the basis of this information we can define the useful strategy of forest management and silviculture attributed to the minimalization of the negative effects of the forest destruction on the keeping of its ecological functions. The forest ecosystems in the Ore Mountains were afforestated mostly on a broad empirical basis. Only the progressive verification of concrete technical methods helped us to elucidate the ecological coherences of damage to forests that are the scientific basis of the directed forest restoration.

CHARACTERIZATION OF THE AREA AND THE FOREST ECOSYSTEMS

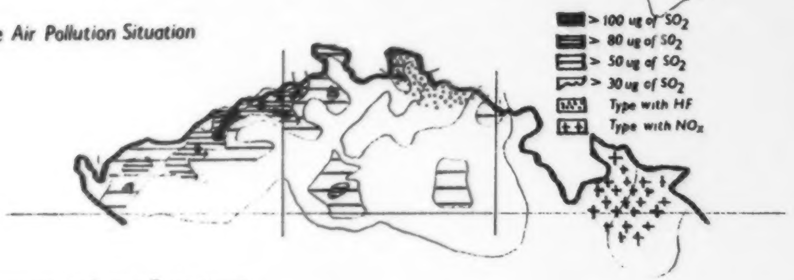
Fig.1

1:3 500 000

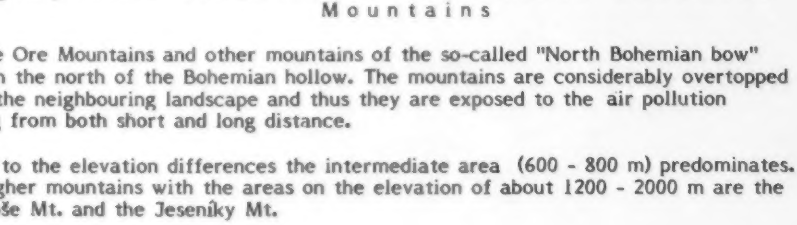
The Geografical Situation of The North Bohemian Mountains


■ > 1100 m
> 800 m
▭ > 500 m
▨ cities
51°
50°
14°
17°
1
2
3
4
5
1 The Ore Mt. (Erzgebirge)
2 The Jizerske Mt.
3 The Krkonoše Mt.
4 The Orlické Mt.
5 The Jeseniky Mt.

The Air Pollution Situation


■ > 100 ug of SO_2
▤ > 80 ug of SO_2
▤ > 50 ug of SO_2
▭ > 30 ug of SO_2
▨ Type with HF
⊞ Type with NO_x

Damages to Forest Ecosystems


■ Substitute stands
▨ Full decomposition
▨ Phase of decomposition
☐ Slightly affected

Geographical Situation of the North Bohemian Mountains

The Ore Mountains and other mountains of the so-called "North Bohemian bow" close in the north of the Bohemian hollow. The mountains are considerably overtopped above the neighbouring landscape and thus they are exposed to the air pollution coming from both short and long distance.

As to the elevation differences the intermediate area (600 - 800 m) predominates. The higher mountains with the areas on the elevation of about 1200 - 2000 m are the Krkonoše Mt. and the Jeseníky Mt.

Air Pollution Characterization of Forestry Areas of the North Bohemian Mountains

The air pollution situation has been deteriorating distinctly during the last decades. In the area of the Ore Mountains the deterioration was significant in the 60s´and 70s´ particularly, in the other areas mainly in the 70s´and 80s´and the trend is still going on here.

The most important air-born pollutants are the compounds of S, especially SO_2. During the last decade other pollutants have started to play a significant role. From this point of view there have been found 8 basic air pollution types up to now (Materna 1988). The air pollution type is determined by the dominant pollutant or the synergy of pollutants or by the synergy of pollutants and particular conditions of the area.

1. The type with dominant SO_2, additional pollutants are NO_x, HF and dust. This type is predominant in the Ore Mountains.
2. The type with co-dominant SO_2 and HF, additional pollutants are NO_x. This type is typical of the Jizerské hory Mt. and the Krkonoše Mountains.
3. The type with strong acid deposition (naturally acid bedrock). SO_2 is measured at lower levels. The typical areas are the western parts of the Ore Mountains.
4. The type with the occurrence of the fytooxidants (O_3 etc.). This type starts to be typical for the parts of the Jeseníky Mt. and some localities in the Ore Mountains.

Other types are interesting but from the point of forest management they are not of primary importance.

Damage to Forest Ecosystems

The damage to the forest ecosystems was spreading at different time levels. The oldest air pollution area are the Ore Mountains; later, with the increase of both the inland and foreign sources of pollution, the damage extended eastwards. The North Bohemian Mountains are the most affected region in Czechoslovakia at present.

The forest ecosystems are influected by immissions on the whole 100 % of the areas. About 45 % of its acreage is at the stadium of affection with visible symptoms of damage, with depressed immunity. This concerns the mountain foothill areas and the protected walleys. About 40 % of the ecosystems are at the stadium of decomposition at which they lose their autoregulative abilities and the forests lose the production role. At the stadium of full decomposition it is about 10 %. This phase could be characterized as the immission clear cuttings with, up to now, not ensured cultures. In some regions there are dying rests of the recent stands. The oldest and the most affected parts of the Ore Mountains are in the phase of the so-called substitute stands (about 5 % of the whole area). The replacement forest stands were established from tolerant species, convenient to the site conditions that partly fulfil the ecological roles but are of the minimal production importance.

Under the SO_2 dominant influence the elevation gradient plays an outstanding role in the damage dynamics (Tesař 1983). The differences in the dynamics depends on the regularities, given by the exposition to the immission flow. The knowledge of these regularities makes it possible to predict the damage development. The other pollutants are substantially accelerating the process of damage more or less. The new structures of pollutants (NO_x, O_3) and their synergism with the changing ecological conditions cause disturbances of the former schemes and the prognosis is loaded with a risk.

The Composition, Status and Function of the Forests

High profitableness of forest management was based on growing Norway spruce (Picea abiesKarst.) which provided high volume production of timber. Norway spruce absolutely predominated in the composition of the stands. Within the framework of the functionally integrated forest management, the other roles of forests were proportionataly ensured. The highest vegetation belt was naturally covered with a climax spruce ecosystem. Above the alpine timber line there is the Mughetum belt in the Krkonoše Mountains and the Jeseníky Mountains.

The natural composition of species in the lower belts was determinated by the prevailing occurrence of Beech (Fagus silvatica) and Fir (Abies alba). The ecological stability of artificially planted stands in these belts is the higher the more similar are the stands to the natural composition. The cultural pure spruce stands prove to be unsteady. Moreover those stands which were not established from the autochtonic populations were damaged by air pollution in the most rapid way. On the special sites where the forest was utilized to serve the purpose of ecological protection (upper parts of the mountains) silviculture measures have not been carried out for several decades. The old unthinned forest stands are more sensitive and the progress of damage is very rapid too.

WAYS OF RESTORATION OF DAMAGED FOREST ECOSYSTEMS

The Latest Strategy of Afforestation

The so-called ecological disaster began after the first signals in 60s´. The forest management had to react immediately, not having any knowledge and operating on a very poor theoretical basis. The first complex strategy of management was worked out in 1957. The original effort was to follow the line of the traditional spruce management. After some time Norway spruce was substituted by introduced Spruce species which were cosidered to be more tolerant than Norway spruce. Of all these species Blue spruce (Picea pungens) proved to be the most sufficient. The effort to prevent timber losses led to clearcuttings on large areas. The unproportionally increased quantity of work resulted in using heavy mechanism (dozers) for the soil treatment. Consequently the large scale production of transplants (Blue spruce) increased considerably. Both these measures caused enormous energetic input into afforestation. The fine biological activity began to be more industrial. The basis strategy kept the same position - traditional cultivation of transplants. Unsuccessful afforestation was repeated mostly in the same way. Fortunately there were small spots with naturally regenerated groups of autochtonic species (Betula sp., Sorbus aucuparia) which had been considered to be weed species in the traditional spruce management. A certain break was caused by the research work that evaluated the importance of these stands (Jirgle 1984) from the point of view of the ecological roles. After some introduced species had failed (Picea omorica, Picea nigra, Picea glauca atc.) the restoration began to be oriented from the "technical" way to the "ecological" way.

The Present Strategy of Afforestation

The strategy of the basic reconstruction of the damaged forest stands utilizes the natural succession processes (Tesař 1988). The forest stands in the Ore Mountains were liquidated and large areas were afforestated. In other North Bohemian mountains the clear cuttings would result in the depression of the alpine timber line will drop by 100 m according to the present line of 1250 m (Lokvenc 1984). In the mountains without the natural alpine timber line e. g. the Orlické Mountains the ecological conditions, after felling down the stands are similar to those of the natural alpine line.

Regarding ecological risks it will be necessary to decide where the stands can be clearcut on a larger scale. This marginal measurement often brought an unpredictable feedback. It is important to decide where it is more economical to keep the damaged trees in order to help to protect the new generation of the stand. The regeneration period of these rests of stands is usually short because of the increasing dynamism of damage. Therefore these protective stands must be used in a most effective way. They should be orientated against the critical influence of air pollution so that they can protect the new generation of forest laterally. The resulting direction of the so-called air pollution flow is locally modified by the terrain. This direction could be simply identified by means of the relative strong symptoms of damage to the individual part of the forest landscape.

The afforestation under the protective influence of the original stand requests sensitive regulation of the canopy due to the light demands of the new generation. This procedure is technically rather difficult. It should be applied particularly in sites where the forest has unreplaceable soil and climate protective roles and it is necessary to keep it until it is substituted by a new generation. In the exposed sites the underplanting or undersowing by Mountain ash (Sorbus aucuparia) should be taken into account.

The success and the economic profit of restoring the forest ecosystems in exposed air pollution areas depends, more than in other areas, on the principle linking up particular biotechnic measures. A large complex of ecological and biotechnical (silvicultural) problems is solved and it is necessary to work upon a special project of afforestation. These projects are carried out on two levels. Either the conceptional level aimed at the large groups of stands solving the whole process of afforestation, or a short time direct realization projects aimed at some particular process in the course of afforestation. The projects as a whole involve the spatial and durative procedures of cutting so that their protective influence could be effectively utilized. Other components of the projects are, inter alia, the way of soil treatment, soil ammelioration, spatial ajustment of individual species and ways of increasing the vitality of new forest ecosystem.

The Air Pollution-Ecological Conditions of the Forest Restoration

The large scale disintegration and the liquidation of the forest stands results in the large clearcuttings with changed climatic regime, the soil features and the cenotic relations. The ground climate is of the lower roughness of the surface. The strongest air pollution flow (synergy of the air flow and concentration of pollutants) is the most serious stressor. The temperature amplitude is getting to be larger and most of all the frequency of ground frosts increases at the beginning of the vegetation period. These frosts injure directly the assimilation organs.

The hydric regime of soil is changing too. The soils with the increased level of underground water during the course of the disintegration of the stands are getting to be dry. From the point of view of the hydric functions the retention of the horizontal precipitation (foggs) disappears. These precipitations have improved the amount of the vertical precipitation by more than one third.

The effects of changes in the soil chemism are also very serious. The long term deposition of ionts and protons, especially on higher elvations causes the increase of the soil acidity, losses of soil nutrients from the upper soil layer, increase in AL and MN concentrations in the soil solution, and the consequental changes in the soil microflora. All these changes are different in individual areas according to the acidity of the geological bedrock.

The loss of the dominant component of the species to the benefit of the covering by Callamogrostis villosa, causes new biocenotic relations. These relations still intensify the opposition to the afforestated species. The continuous grass cover influences alleopatically the plant roots.

The long term ecological unbalance makes unnatural gradation of small rodents possible (Microtus agrestis etc.).

One of the most dangerous agents is the game. Traditional protection is impossible on large clearcuttings (often larger than 100 ha). Modern ways of the protection have met with a small effectiveness. The only, but very difficult way is to reduce the number of game.

The new environment starts to be optimal also for harmful pests and pathogenic fungi.

All these stress factors are outstandingly unfavourable for young cultures. Under these circumstances the permanent prosperity of most economically valuable species (Beech etc.) is impossible. The only solution is to plant the so-called pioneer species sufficiently adaptive to the continually changing environmental conditions in the first phase.

Species Available for the Afforestation of Extreme Air Pollution Areas

In the Ore Mountains the composition of tolerant tree species has been already selected for the climatic and biotic stress factors. From the introduced species Blue spruce has brought the most positive results up to now. Its priority is, in the first place, the higher biomass of needles in comparision with Norway spruce and other introduced conifers (Tichý 1989). As far as Blue spruce keeps its tolerancy even in further environmental conditions its cultivation will be justifiable especially in areas with the water-economic aims.

The number of broadleaf species is more rich. The pioneer species with a large ecological amplitude have passed through selection. The most reprezentative species of this sort are Birch (Betula pubescens, carpatica) and Mountain ash (Sorbus aucuparia). These stands have, above all, the soil protective roles. Their importance in the strategy of further afforestating of the economically valuable species should not be underestimated. The other used species is Larch (Larix decidua) which has proved its tolerancy to the chronic damage. In the episoidical situations with the extremely high level of SO_2 concentrations or high level of other pollutants (O_3) larch has proved to be less tolerant. It creates the rich aboveground biomass. Its cultivation has met, however, with little success on moist and peaty soils. In the region of the Ore Mountains other species have been cultivated during the last thirty years. Most have survived in in small refuges without any substantial importance. Among other tested species Alders (Alnus viridis, incana), Aspen (Populus tremula) could be mentioned. The naturaly regenerated Salix caprea has lately begun to be of a certain importance. The research on this subject has not been finished so far. For example the pioneer pine species (Pinus contorta) are being tested at present.

In other North Bohemian Mountains the restoration of forest ecosystems will be based more on the autochtonic tolerant species. The changed environmental condition close to the natural or artificially dropped alpine timber line correspond to the use of Mountain pine (Pinus mugho). Even though this species has the initial symptoms of damage it has wide ecological valency and a high potential of roles. Norway spruce should be represented at least in 30 % (contrary to the late 95 %). In the upper parts Norway spruce will not be able to survive the changed environmental conditions in any of the given areas. In the lower parts Norway spruce demands ecological protection.

The introduced conifer species will be used to a smaller extent than in the Ore Mountains. The specification of broadleaf species is practically the same as those which have proved in the Ore Mountains. With respect to the experience of the course of the air pollution calamity in the Ore Mountains the order of species will be rather different due to the natural succession of species in different phases of the destruction of the ecosystem and different site conditions. In the region with the lower air pollution level it will be possible to work with a large scale of autochtonic broadleaf species (Acer sp., Oak sp., Fagus etc.).

CONCLUSIONS

The above mentioned information gives a picture of the valuable experiences in forest management in the air pollution areas of the North Bohemian geographical region. The restoration of the extensive extreme localities is absolutely necessary for important environmental and ecological reasons. It is clear from experience, including some expensive mistakes, that the ecological attitude which follows the line of natural succession is much more convenient than the traditional afforestation procedures.

The established stands have, or will have, a quite different composition (compared to the late composition) of species, an uneven structure of the stands is characteristic too. The potential of roles will by no means achieve those of the original climax spruce stands. But from the point of view of the forest management this substitute forest stands mean an indisputable success and they are probably the only possibility of the future speedy return of the original climax ecosystems.

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CONVERSION AND PRESERVATION OF FORESTS DAMAGED BY AIR POLLUTION IN THE HIGHLANDS OF THE GDR

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FDC: 425.1: 425.3: 181.45: 62: (430.2)

Summary

Forest damage caused by air pollution covers a large area in the highlands of the GDR. Formerly, waste gasses containing SO_2 were dominating, recently numerous other pollutants have joined. In converting damaged areas the choice of tree species plays a special role, because in addition to the original site environmental changes, which already occured or are expected in future on account of anthropogenic influences, have to be taken into consideration.

The often very extreme environmental conditions prevailing on air-polluted areas require special care and various additional expenses for regeneration.

Damaged, but still viable older spruce stands are for a possibly long period managed according to principles of graduated thinning from below. Physiological and mechanical wind blast playing an important role in the highlands of the GDR. These effects are to be minimized by applying a proper felling system. For air-polluted regions of greater extent conversion projects, which at the same time take ecological, technological and economical viewpoints into consideration, are required.

Keywords: amelioration, choice of tree species, conversion projects, environmental modifications, felling system, fertilization, pioneer tree, sylvicultural planning, technology of regeneration, tending, thinning, tolerance of tree species

1. Introduction

Since the end of the fifties big areas of spruce forests growing in the Ore Mountains (Erzgebirge) have been damaged in a different mode because of air pollutions, particularly by SO_2. In the last ten years also other highlands of the GDR (Harz, Thüringer Wald) and partly also lowlands and hilly landscapes have been subjected to further stress factors such as NO_x, NH_3, O_3, PAN as well as to extreme weather conditions. These effects brought about different symptoms and damage-causing processes. Therefore it is indispensable to distinguish between different types of air pollution and symptoms which in part show not yet sufficiently clarified relations of cause and effect and therapeutic measures.

In spite of this, in the following an attempt is made to outline general principles of silviculture in the highlands of the GDR that are damaged by air pollution. Two tasks are dealt with in this connection:

1. Regeneration after stand destruction and clear-cutting (strategy of conversion)
2. Further treatment of the still present or already newly established stands in the damaged regions (strategy of preservation).

2. Conversion of no longer preservable forest stands

Forest stands that have been so heavily damaged by air pollution or that will be subject to damage in the next few years to such an extent that they are no longer capable of fulfilling their productive, protective and recreative tasks will be gradually converted. In this case the choice of tree species and reafforestation technique are of major importance.

2.1. Choice of tree species

In air-polluted areas the choice of tree species is very difficult. Trees are long-lived and reaching of targets linked with their growing takes periods ranging from some to many decades. For this reason when choosing the tree species one cannot merely proceed from the present-day environmental and site situation; moreover, the environmental changes and stress caused by pollutants within the given rotation time have to be considered with regard to kind, duration and concentration. The basic problems arising in this connection are shown in fig. 1.

In this figure the habitat of a species is characterized by a rectangle. Here, t_{μ} is the normal life expectancy and U the environmental amplitude of the species concerned. Both are genetically coined. Within this rectangle the reactivity RJ = f (t,U), e. g. the increment, is shown by isolines. If the environment U = f (t) changes, reactivity will change as well until mortality sets in at the tolerance limit. This

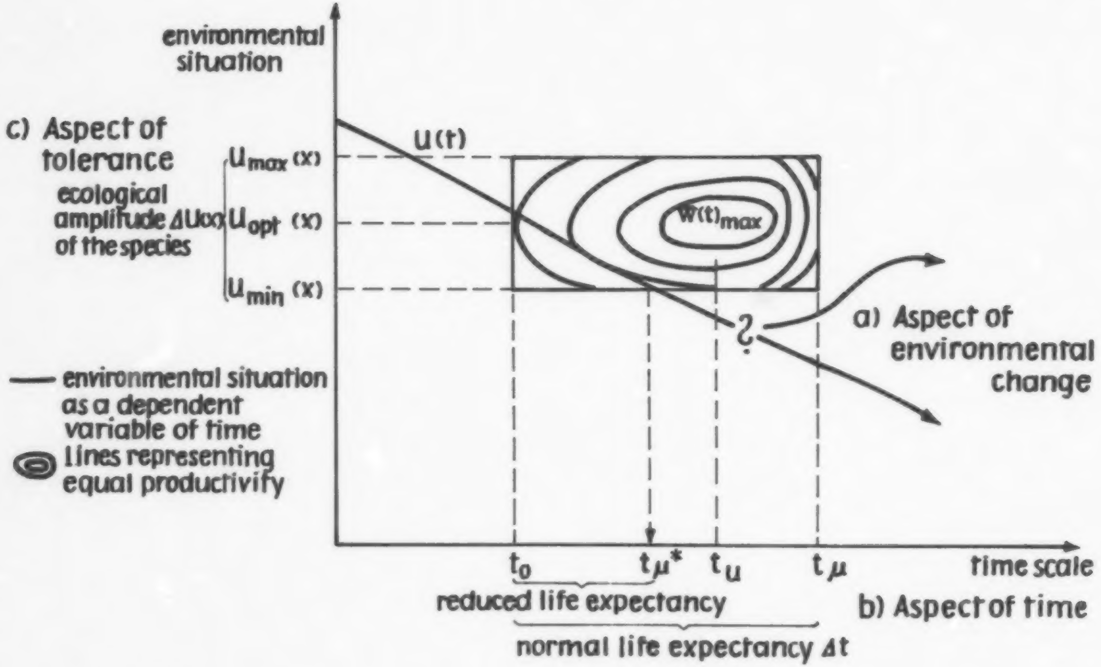
environmental situation
c) Aspect of tolerance
ecological amplitude ΔU(x) of the species
$U_{max}(x)$
$U_{opt}(x)$
$U_{min}(x)$
U(t)
W(t)max
?
a) Aspect of environmental change
— environmental situation as a dependent variable of time
lines representing equal productivity
t_0
$t_\mu{}^*$
t_u
t_μ
time scale
reduced life expectancy
normal life expectancy Δt
b) Aspect of time

Fig. 1 : Ecological amplitude $\Delta U(x)$ of a species x, its normal life expectancy (t_μ) and in consequence of environmental changes reduced life expectancy ($t_\mu{}^*$) as well as the productivity W (t) resulting from the time t and from the environmental situation U (t)

is the earlier the case the higher the speed of change $\frac{\Delta U}{\Delta t}$ and the narrower the ecological amplitude U (x) of the species, race or sort concerned. Hence, three aspects will follow:

a) Aspect of environmental modification

Because of the long-term nature of production processes in forestry the environmental changes expected in these periods of time have to be taken into account.

This refers in the first place to the modification of air-pollution stress determined by kind and concentration together with the soil processes resulting herefrom. In addition to this climatic changes which can probably be apprehended as a result of the greenhouse effect have to be taken into consideration.

b) Aspect of time Δt

Long-lived organisms are more endangered by environmental changes than short-lived ones

- because relevant environmental changes are more probable in a longer period of time than in a short one
- because longevity is mostly linked with a smaller sequence of generations and thus with a worse adaptability to environmental changes.

Therefore only those tree species will be suitable for cultivation the life expectancy of which surpasses the rotation period also under conditions of air pollution or under other environmental changes.

c) Aspect of tolerance ΔU (x)

The ecological tolerance of the various tree species, races and sorts is of eminent importance for their behaviour under the conditions of air pollution stress and environmental modifications. Taxa which distinguish themselves by a large ecological amplitude (e. g. pioneer trees) are therefore in most cases characterized by a greater resistance to corresponding stressors. As ecological tolerance is often coupled with genetic diversity its restriction often heightens also the risk.

The best results in conversion have been achieved with larch. Here, it refers to Larix decidua Mill. and Larix kaempferi (Lamb.) Carr. and their hybrides. Moreover, larch stands are well suited for later underplanting by means of Fagus silvatica L. and other shade-tolerant trees.

When converting our highlands an essential increase of beech has to be aimed at for a long period. In the natural forest of mountain regions Fagus silvatica L. had been the dominant tree species in these originally mixed stands. Since in all SO_2-polluted regions it proved to be relatively resistant it must be preserved and regenerated in places where it is found still today.

At locations where it had been crowded out in the last century by spruce (Picea abies (L.) Karst.) Fagus silvatica L. is to be reestablished using overhead shelter and side cover of pioneer crops and conversion stands or under microclimatically favourable ground conditions.

Also valuable broad-leaved species such as Acer pseudoplatanus L. and Fraxinus exelsior L. have proven to be relatively SO_2-resistant. On eutrophic and fresh sites they cannot be left out when converting polluted stands. In this connection Alnus glutinosa (L.) Gaertn. should also be mentioned.

On extreme sites at high altitude and crests with acid and oligotrophic locations, where originally only spruce stands (Piceetum) occurred, lodgepole-pine (Pinus contorta Dougl. (ex Lond.)) (in spite of manifold hazards by honey fungus and game) and Macedonian pine (Pinus peuce Gris.) can be an alternative.

Less satisfactory is blue spruce (Picea pungens Engelm.) which had often been cultivated in the past few years. It grows very slowly, is branchy and the stands composed of this species often show already during the seedling and sapling stages large mortality gaps due to honey fungus, needle-eating insects and other pests.

Furthermore, it had to be taken into account, that the future forests also need a differentiation according to age and space in the system of management. As a consequence already nowadays the future space-time-pattern has to be prepared in connection with large-scale conversion by an adequate spatial arrangement of types of growing stock with different rotation times. In consideration of a long-term experience and of results achieved by research work in forest tree breeding and forest ecology proposals of tree species differentiated according to site were made and fixed in official rules.

Among the indigenous tree species the pioneer trees Betula pubescens Ehrh., and Betula pendula Roth., Populus tremula L. and Sorbus aucuparia L. should be first named. In most cases they grow spontaneously, but they can also be sown or planted. These pioneer trees are important in two respects:

- for the formation of a pioneer crop under their canopy more demanding tree species such as beech (Fagus sylvatica L.), sycamore (Acer pseudoplatanus L.), ash (Fraxinus excelsior L.), Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) or various fir species (abies) can be grown.

  For this aim primarily trophic and hygric medium as well as better sites situated in the lower and medium mountain regions will come into question

- for the formation of independent pioneer stands that if the occasion arises could be cut after a short rotation period and replaced by other tree species. For this purpose above all climatically and edaphically unfavourable sites are concerned, e. g. on wet and swamp sites white birch (Betula pubescens Ehrh.) and on shallow and dry sites sand birch (Betula pendula Roth).

Picea omorica (Panc.) Purk can be recommended in the lower and medium-altitude mountainous regions on sites with medium and poorer quality. Here, it distinguishes itself by relatively fast juvenile growth. In ridgy regions characterized by extremely high SO_2 stress the cultivation of this tree species which is somewhat more exacting in view of a warmer climate will pose already some problems.

2.2. Technology of regeneration

2.2.1. General viewpoints

Crops cultivated under extreme environmental conditions in regions stricken with air pollution should be given favourable starting conditions.

That's why additional expenses for pretreatment of the area, soil preparation, fertilization and amelioration, for choosing the planting stock and tending plantations will be necessary and justified:

- Uncovered soil due to large-scale clearings should be avoided because of ecological problems that will arise. Wherever feasible, a timely preliminary crop or planting under cover should be aimed at.
- When uncovered soil as a result of large-scale clearings will be unavoidable, everything will have to be done to mitigate the resulting extreme conditions (moisture, frost, heat, decomposition of humus and nutrient losses).

From the edaphic and microclimatic point of view the following is desirable:

- to preserve organic substances as nutritive foundation of soil organisms, as nutrient reservoir, buffer substance, complexing agents (Al-ions) and as soil physical factor
- to preserve the ecologically useful associate flora as nutrient receivers, humus producers and microclimate transformers.

On account of afforestation technology this is opposed by

- the danger of desiccation of plants when they develop roots only in the humus layer
- the competition arising due to wild-growing herbs and grasses and due to pioneer trees.

Between these partly contrary points of view compromises will have to be found which will consequently be expressed in the corresponding technological rules for afforestation.

2.2.2. Principles of regeneration

Despite all differences in site and tree species some rules of regeneration on air polluted areas can be stipulated:

- regulation of soil moisture by means of hydroamelioration, planting on ridges or small dikes, if necessary
- mechanical comminution of slash on the area (target) or deposition on small dikes (still dominant at present)
- in case of covers consisting of tall grasses (especially, Calamagrostis villosa (Chaix) Gmel.) which are a factor of strong competition with respect to the succeeding crop, areas will be pretreated by herbicides, if not otherwise prohibited; subsequent weeding and tending operations will be decisively facilitated by this measure.
  Wild plants exerting no negative influence on crops (Senecio, Digitalis, Epilobium) will be spared.
- soil preparation on lines and spots, in the course of which the humus layer will be either preserved up to a distance that can be reached by roots or mixed up with mineral soil. By pushing off the lawn, humus and sticks planting work and growth of plants will undoubtedly be facilitated in the first time, however, it will bring about a depression of growth in the seedling and sapling stages. This is supplemented by high costs and considerable losses of area due to dikes. An amelioration procedure applying complete ploughing, liming as well as K-P-fertilization was developed for acid loam-pseudogleye-soils.
- fertilization on sites and tree species, where nutrient deficiency occurs or must be apprehended.
  This type of fertilization will be mainly applied to plant holes and planting rows, because the danger of competition due to wild-growing herbs and grasses will be increased by widely spread surface fertilization.

  The following aspects are suitable for this purpose (FIEDLER 1988 a, b):

  - potassium fertilization on sites rich in skeletal soil situated above quartzitic parent rock (to some extent also for supporting resistance to frost)
  - fertilization by phosphorus on rhyolite- or quartz porphyry sites
  - fertilization by lime aimed at improving pH value and slackening of P fixation in mineral soil. Liming is carried out in combination with additional nutrients. When planting beech (Fagus sylvatica L.) and sycamore (Acer pseudoplatanus L.) or other exacting tree species on sites with medium and low nutrient content fertilization is necessary
  - Magnesium fertilization required in many places is linked with liming on the foundation of dolomitic limestones.

Nitrogen fertilization can be omitted in plantations because increased humus decomposition on open ground as well as the supply of nitrogen from the atmosphere will ensure a nitrogen supply sufficient for the seedling stage.

- Only big and strong plants are used for regeneration in air-polluted areas, in order to withstand the extremes of open ground the competition resulting from associated flora as well as the danger proceeding from game and pests.
  In the past few years the proportion of container and substrate plants has risen considerably, because they can be planted in any season by unskilled labour. In this respect your attention must be drawn to the danger of root deformations, especially in small containers.
- Plants with nacket roots have to be planted in the optimum season very carefully. In this connection it must be assumed that root deformations (angle planting, machine planting) will bring about predispositions for the attack by honey fungus.
- Forest plantations occurring in air-polluted areas demand very intensive pest control, especially against weevil and other pests occurring in plantations.

3. Strategy of preservation

3.1. General viewpoints

Because of the very important productive, protective and recreative functions of our forests as well as because of the reductions in air pollution to be expected in the next decades everything has to be done that can contribute to an improvement of the state of health, to a decrease of all the damage and delay of damage progression and consequently to the outliving of the present situation.

In this connection three principals are of general importance:

1. The general state of health of a forest stand is the resultant of numerous environmental factors (climate, nutrient and water supply). Therefore, everything possible from the technological point of view and everything that can be justified from the viewpoint of economy has to be done, in order to favour ecological conditions of forest stands stressed by air pollution.
2. In air-polluted regions, it will be necessary to provide for a sufficient stability of trees and forest stands against such injurious factors occurring in clean-air regions, too. This applies, above all, to snow, storm, game, insects and fungi. That's why, everything, possible has to be endeavoured to be in an position to stabilize trees and forest stands also in the face of injurious factors of this kind.

In the treatment of stands the future development (degree of endangering by MATERNA and TESAR (1989)) probably resulting has to be taken into consideration by estimating life expectancy of each individual stand and by prospective planning of silviculture.

3.2. Basic principles with regard to preservation of forests

3.2.1. Improvement of ecological conditions

3.2.1.1. Fertilization of stands

From the natural conditions of sites, the input of atmospheric impurities, the leaching of nutrients and the removal of substances thanks to biomass production and utilization follows for each definite location a specific soil-chemical situation as well as a state of nutrition for the trees growing on it. Forest fertilization is outlined and implemented on this foundation (analyses of air, soil and needles).

Since in the GDR forest damage occours predominantly on soils and periglacial layers of debris of acid parent rock (granites, quartz porphyries, quartzites, sandstones and others) as well as on sites characterized by strong inputs of protons (very foggy and rainy mountainous regions), here, a reduction of acidity and an increase of basicity (especially Ca, Mg, Zn) by means of fertilization is aimed at. For this purpose we use dolomitic limes, dolomitic limes with readily soluble Mg components as well as magnesian and Zn-containing commercial limes (FIEDLER 1988 a). More than 100 000 ha have been fertilized with Ca and Mg on the territory of the GDR in the past three years. Additionally, there was, in most cases overlapping, application of liquid fertilizers on the basis of Mg-chelates in places where solid fertilizers would not have become effective in due time. On special sites P- and K-fertilization (the latter mainly against frost damage) can be expedient.

3.2.1.2. Hydro-technical amelioration

Opening of forest stands and exposed soil will cause damming wetness on depressions of ground and on plateau without drainage due to reduced interception and evapotranspiration.

This water logging, which is detrimental to root formation and consequently to tree growth as well as to the stability of trees, can be counteracted by means of hydro-technical amelioration. Often it is possible to reconstruct old already decrepit ditch systems. Otherwise, the runoff opportunity has to be provided by constructing new drainage ditches, and the hydrological situation to be improved.

3.2.1.3. Modification of microclimate

Movement of air and together with it the flux of pollutants, filtration of pollutants and physiological and mechanical actions of the wind are greatly influenced by the space structure of each individual forest stand and by the spatial arrangement and dimension of forest stands. In polluted regions air movements with higher intensity together with their mechanical and physiological accompanying symptoms have an aspecially detrimental effect on the state of health and the resistance capability of trees and stands.

In this connection one has to differenciate between the individual forest stands and crop complexes.

In the forest stands, filtration of pollutants as well as physiological and mechanical actions of wind are strongly influenced by the space structure (stand density, tree dispersion, stratification). This in turn depends on the set of tree species and age spectrum as well as on the intensity and method of thinning.

In this connection the following applies:

- weak thinnings and high stand density will reduce wind velocity in the stand and thus the penetration of air masses as well as the filtering action of the canopy.
- thinning from below will cause a lower surface roughness than thinning from above and will, consequently, result in a lower filterung effect.

These aerodynamical effects are contrary to dendrophysiological viewpoints:

- Density of forest stands corresponds with strong competition between trees. Shortage of growing space favours the acrotonic growth of trunk and inhibits the other growth components, mainly the radial increment and root growth with all consequences resulting form ist.
- The low supply of light within dense one-storeyed stands shortens the life time of the needles inserted into the lower crown region and causes an earlier and more intense self-pruning. This leads to a lower needle mass, a reduced individual productivity as well as to a higher risk towards all factors causing a further reduction of the photosynthesizing apparatus (needle-eating insects, topbreak etc.).

The efficiency of the contrarily acting factors is obviously age-dependent, as appears from numerous results of stand analyses with regard to the sociological position and the degree of injury.

After evaluation of available publications, research results and observations the conclusion can be drawn that in young stands preference has to be given to dendrophysilogical viewpoints for the purpose of developing large, symmetrical crowns and high amounts of needles. However, in less protected older stands of grater tallness preverence has to be given to aerodynamic requirements for the purpose of decreased air movement and pollutants retained by filtration. In the terminology of silviculture it reads: low density in young, big density in old stands or "graduated thinning" (in German language "Gestaffelte Durchforstung"), respectively.

When taking the level of crop complex into consideration the surface as seen from the standpoint of physiography and stand-morphology is of special interest, because it considerably influences direction, strength and turbulence of wind and thus mechanical and physiological stress of stands as well as the filtration process to retain pollutants. In this connection the protective function of land forms and crop complexes extending in front of the weather side are decisive for the individual stand.

On this basis close relations between wind velocity and degree of damage as well as the ability to regererate could be proven at the example of spruce stands in the Ore mountains. This positive effect of a "protecting cover" has to be considered when cutting. All cutting methods which lead to a greater exposure of the leeside stands to wind accelerate the progress of damage. Hence, special attention has to be paid to care and preservation of forest stand borders.

3.2.1.4. Preservation and assistance of tree species tolerant to air pollution

In even-age spruce stands of the highlands greater wealth of species, especially of indigenious bread-leaved ones that are tolerant to air pollution can contribute to improve root formation, humus composition and general stability. Here we have it to do in accordance with the natural forest communities predominantly with red-beech (Fagus silvatica L.) and sycamore (Acer pseudo-platanus L.) on sites containing medium to high content of nutrients, being well supplied with water, with ash (Fraxinus excelsior L.) and alder (Alnus glutinosa (L.) Gaertn.) growing on sites with ground water flux and pioneer species such as Sorbus aucuparia L., Betula pubescens Ehrh. growing on extreme sites at high altitude and on crest sites as well as Betula pendula Roth. growing in mountainous regions at low and medium altitudes. These tree species often occur spontaneously in sparsely stocked spruce stands. In air-polluted regions they should be preserved and assisted more than as is usually the case.

3.2.2. Stabilization of forest stands against noxious factors appearing as in clean-air-regions

At high-altitude and crest sites in the highlands where hitherto heaviest air-pollution damage has been observed spruce stands are to a great extent exposed both to snow and storm. Thus, when tending air-polluted forest stands these dangers must equally be taken into account.

Stabilization of the individual trees is provided by establishing and tending young stands with low density. In this way low h/d values and long symmetrical crowns are achieved.

Wind load acting as a horizontal force as distinguished from snow is however to an essentially greater extent dependent on the stand density, because latter excerts a considerable influence on the wind velocity (MARSCH 1989).

In consequence of the more effectively reduced wind velocity within the stand dense and evenly closed stands are less endangered than sparsely stocked and open ones.

Both viewpoints

- low density in young stands to increase the individual stability against snow
- high density in old stands aiming at increasing collective stability against storm

can again be only brought into accord by means of graduated thinning. Herefrom results the extremely important conclusion, that the silvicultural treatment of spruce stands endangered by air pollution as well as snow and storm requires graduated thinning.

In air-polluted regions monitoring, prognosis and control of pests of all kind is of special importance, because here the trees and forest stands can be physiologically weakened, their resistance mechanisms diminished and the effect of certain feed-back mechanisms reduced (antagonist potential).

4. Treatment of stands, silvicultural planning and elaboration of conversion projects

In air-polluted regions silvicultural planning ist complicated by additional, often not readily calculable influencing factors such as kind, concentration and duration of the effect of the respective noxious substances as well as synergisms of several noxious substances. After studies over many years of the course of damage dependent upon dosage and site in the Ore Mountains it is nowadays possible to make certain predictions concerning further stand development. For this purpose, a model by MÄKELÄ (1987) based on the effective sum of temperatures, a model considering wind velocity by LIEBOLD (1988) and a table by MATERNA, KLIMO and KŘIŠTEK (1989) based on the absolute altitude, are available.

Forest stands that will probably disintegrate in the next 10 to 20 years (falling below a stockung degree of 0,5) are to be regenerated in due time by advance planting in order to avoid ecological problems (water logging, frost, heat, humus decomposition, nutrient losses, competition by wild-growing herbs) arising after clear cutting.

Such measures can of course be planned not only from the viewpoint of an individual stand, they rather require special planning for air-polluted forest regions of greater extent. In such conversion projects ecological, technological and economical viewpoints have to be considered equally.

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Voluntary Paper Summaries
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Zusammenfassungen der unaufgefordert vorgelegten Beiträge
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PSYLLID INVADING SAXAUL TREE IN IRAN

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SUMMARY

FDC: 453: 416.13: 176.1 Haloxylon spp.: 145.7 Psyllidae

This insect is an important pest of Saxaul trees (Haloxylon spp.)in Iran. Its directly feeding on leaves and making galls causes a severe damage on Haloxylon plantations. According to the reseach carried out on this plant in Iran(1985 - 1989),now it is quite clear that this psyllid has 3 generations anually and third nymph instars.

In spring of the subsequent year , the nymphs feed on young twigs and make a number of galls amongst the branches, Their eggs are white,with pear shaped. Eggs are laid on intervals of young shoot joints, around the axis of twigs so that distal ends of them are merely visible. The maximm of 20 eggs are laid on each joint space and they hatch after 7 days .Nymphs start to feed and to make galls immediately.

Keywords: Morphology, bioecology and life cycle

GROWTH AND FOLIAR NUTRIENT ACCUMULATION OF THREE POPLAR CLONES IN NINEVAH PLANTATION

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SUMMARY

FDC: 181.34: 181.65: 232.322.411/414: 232.328.1/.2: 176.1 *Populus* spp.

Growth and seasonal nutrient concentration, content, and dry matter accumulation for three local clones of poplar (*Populus nigra* IRQ-1, *Populus nigra* "Babylon" IRQ-6 and *Populus X euramericana* IRQ-19) were studied between February and October, 1988 in Ninevah Plantation. Three levels of N, P, K fertilizers O, 18 and 36 gms/seedling were applied twice, at the beginning of May and August to the seedlings raised by using stem and root cuttings. The results showed that root cuttings can be considered as sources for establishing plantations. Clonal differences in response to N, P, K fertilizers were evident. *Populus nigra* "Babylon" IRQ-6 respond signfiicantly to the application of N, P, K at early May. Regression of nutrient content and leaf dry weight indicate high correlations, this relation could be used for predicting the amount of nutrient elements removed with dry matter during harvesting.

EFFECTS OF PACLOBUTRAZOL AND ITS METHOD OF APPLICATION ON THE GROWTH AND TRANSPIRATION OF *ACACIA MANGIUM* SEEDLINGS

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FDC: 161.4: 161.16: 232.329.6: 176.1 *Acacia mangium* Willd.

Delay in field planting always causes containerized nursery grown *Acacia mangium* Willd. seedlings to be over grown. These seedlings are difficult to transport and plant, have an unfavourable root: shoot ratio, and are reported to perform poorly when outplanted. This study was conducted in an attempt to develop an effective manipulative technique to control the excessive growth prior to transplanting.

Ten weeks old potted *A. mangium* seedlings were subjected to a growth retardant paclobutrazol (PP333) at concentrations of 0, 500, 1000, 4000 and 12000 mg/l. Three methods of application were tested i.e. foliar, soil, and foliar + soil. Subsequently, the growth and transpiration of the plants were monitored for 12 weeks at weekly intervals.

Paclobutrazol was found to be very effective in retarding the height, diameter, leaf area and transpiration of the seedlings. Differences between treated and control plants for these parameters were statistically significant from 2 weeks after treatment. The differences were greatest for plants treated by soil or soil + foliar. Reduction in growth and transpiration increased from a minimum at 500 mg/l to a maximum at 12000 mg/l. Differences between concentrations were in general, not statistically significant for the parameters measured.

PROVENANCE VARIATION IN EASTERN WHITE PINE (*PINUS STROBUS L.*): 28TH-YEAR RESULTS FROM TWO SOUTHERN ONTARIO PLANTATIONS

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FDC: 165.5: 232.12: 174.7 *Pinus strobus* L.: (713)

Provenance variation in eastern white pine was investigated on 12 range wide sources established at two test locations (Turkey Point and Ganaraska Forest) in Southern Ontario. Thirteen characters (height, diameter, volume, forking height, survival, forked trees, branches/whorl, secondary flushing, stem form, branch diameter, branch angle, weevil, and blister rust) were measured and scored on trees at 28 years of age. Statistical analysis consisted of univariate, multivariate and non-parametric methods.

Eastern white pine proved to be highly variable and displayed well-defined patterns of variation. Multivariate analysis of seven traits established an east-west clustering of provenances. Regression analysis provided additional evidence of east-to-west clinal pattern for growth and branch angle. At both test sites trees from Atlantic coast had grown fastest, while trees from further inland have been below average performers. Traits such as growth form and resistance to biotic factors showed weakly defined gradient patterns, suggesting randomness. Provenance-environment interactions resulted in significant rank changes for the two planting sites in diameter (DBH), volume/plot, weevil damage, branch diameter and branch/whorl.

Height growth measured at ages 2, 7, 12, 19, 21 and 28 was used to examine juvenile-mature correlations and response to early selection. These correlations for ages above 7 years were generally very high and led to the conclusion that evaluations at seven years or older may be useful in selection of the best provenances.

Symptoms, Foliar and Soil Nutrient Contents for Norway Spruce and Responses to Fertilizer Applications. Aleksander Adamowicz and John M. Skelly, Department of Plant Pathology, The Pennsylvania State University, University Park, PA 16802.

FDC: 424.7: 114.521.3: 114.521.5: 237.41: 174.7 Picea abies Karst. Nutritional deficiencies have been shown to be a direct cause of decline of forest stands observed in Europe and North America. Soil and foliar nutrient analysis is the most useful method for the indication of such deficiencies. Site adjusted fertilization has been shown to have positive effects on declining stands.

Based on visible symptoms of discoloration and needle loss supported by chemical analyses of soils and foliage, three Norway spruce plantations were chosen for potential improvement of declining stand conditions. Two plantations were located in Pennsylvania on a Hazelton and Wharton soil series, respectively. A portion of a previously studied plantation with known Mg deficiency on a Dekalb soil series in West Virginia was also studied. Plantations were 43, 50, and 60 years of age and were at 600, 800, and 1250 m MSL, respectively.

All three plantations showed different degrees of discoloration and loss of older needles. Soil and needle analyses completed in the growing season of 1988, indicated Mg deficiency on all three plantations. In addition, K deficiency in needles was indicated on Plantation No. 3.

Plantations No. 1, 2, and 3 have been divided into 11, 9, and 4 plots, respectively, for fertilizer treatments. In addition to control plots, 2 levels of fertilizer - 50 kg and 100 kg of MgO in 3 replications each were applied in plantations 1 and 2. Only one rate (100 kg MgO and 100 kg K_2O_5) and two replications were used in the WVA plantation. All fertilizers were applied in April of 1989.

In addition to periodic visual evaluation of tree discoloration and defoliation, samples of soil and needles have been taken three times in the growing season of 1989: in April, before fertilization, and twice--in June and November--after fertilization.

Pre-treatment results indicated moderately acidified soils with low, to very low (plantation No. 3) K, Mg, and Ca saturation. Nutrient content in needles clearly showed a deficient Mg supply as well as deficient supply of K on plantation 3. Other nutrients were noted as being sufficient to optimal in supply with high values for N.

In June, two months after fertilization, soil saturation with Mg was significantly higher on treated than on control plots within all three plantations. The same was observed for K within plantation 3. Nutrient content of needles did not show any significant differences between treated and control plots.

In November, six months after fertilization, the differences in the soil saturation with Mg between treated and control plots were greater than in June in all three plantations. However, Mg content in needles did not show any significant differences between treatments and control plots in any of the plantations. Only K content in needles in the WVA plantation was significantly higher on treated compared to control plots. Further tests for change in foliar and soil nutrient status will take place in April-June, 1990.

THE IMPORTANCE OF INSECTS OF REFORESTATION IN THE LIGHT OF CURRENT WORLD FORESTRY PRACTICES.

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FDC: 914: 233: 453: 411/414

A recent report by Robert Repetto, with the World Resources Institute of Washington, D.C., indicates in the entire period since pre-agricultural to the present, the world's forest area declined by one-fifth. However, since World War II, deforestation has accelerated throughout the world, particularly in the developing nations where more than 11 million hectares are cleared annually. Just to name a few examples, between 1950 and 1983, forest areas were reduced by 38% in Central America and by 24% in Africa. These reductions are due to increased population pressures and to government policies, which result in large areas of forests being converted to other uses. Tropical forests, in the Amazon and elsewhere, are being harvested or destroyed at rates that anticipate their demise in a foreseeable future. This causes the degradation of fragile soils, the extinction of wildlife, and the destruction of the livelihood of forest dwellers. In North America, the last remains of old growth forests are disappearing amid growing opposition from the environmental groups and the public. In Europe, where reforestation operations have been part of forestry for a long time, forest decline due to pollution is creating new challenges. Environmental scientists are warning us of the perils of such deforestation for world climate.

An incipient reaction to these can be seen to various degrees in different regions. Accelerated reforestation programs are being implemented in some countries and a commitment has been formulated for a rational resource use in some of the tropical countries. The future will undoubtedly bring worldwide increased reforestation efforts to counteract wood and fiber shortages and environmental degradation. Reforestation pests are a threat to any reforestation program. They affect plantation establishment, reduce growth rates, induce tree deformities, and often lead to plantation failure. Our role as reforestation pest specialists is to ensure that reforestation objectives are met through the use of pest management techniques that are compatible with the environment. Our working group, by fostering the exchange of information among scientists and foresters working on reforestation problems, is making a contribution to ameliorate the world deforestation crisis.

PROVENANCE-AGE INTERACTIONS IN 52 Pinus pinaster AIT. PROVENANCES (ESTUDIO DE LA INTERACCION PROCEDENCIA- EDA[illegible] EN 52 PROCEDENCIAS DE Pinus pinaster AIT.)

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FDC: 232.12: 561.1: 541: 174.7 Pinus pinaster Ait.

Height growth of 52 Pinus pinaster provenances from the species natural range (42 spanish. 2 Portuguese. 5 French. 2 Maroccain and 1 Italian) was studied in a provenance test located in Western Spain.

Comparisons of mean provenance height growth at ages 1. 5. 14 and 18 years old indicated that selection of best provenances can be performed when the trees are 5 years old.

Height growth as a provenance-site interaction was also studied. For every age site quality was defined as the mean plot height. Grouping of provenances consistent with their geographical origin was obtained using two parameters: the mean provenance height at 5 years and the linear regression coefficient of mean provenacne height on quality site for every age.

The followings groups were so differentiated:

Group 1: Atlantic provenances.

Group 2: Small heterogeneus group containing one atlantic provenance and one Iberian System provenance.

Group 3: Provenances from Central System. Cazorla and Segura. and Iberian System.

Group 4: Provenances from Castille.

Group 5: Small heterogeneus group consisting of three Castille provenances and one Iberian System provenances.

Group 6: Provenances from Teleno and Bureba.

INSECT PEST MANAGEMENT IN SOCIAL FORESTRY PLANTATIONS

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FDC: 453: 411/414: (540)

In India as a result of increase in population more than 27 million hectares of forest land has been brought under plough. This had led to scarcity of fuelwood and raw materials for forest based industries. Realising this the Government of India is launching Social and Farm Forestry Programmes on a large scale to meet the food, fuelwood and fodder requirements and to improve the environment. The insect pests such ass white grubs, cutworks, termites, leaf defoliators, stem borers, sap suckers, etc. are some of the biological determinants which limit the productivity in the Social Forestry Plantations. These pests can be successfully managed through silvicultural adjustments and chemical and biological control. This paper gives an account of pest problems in Social Forestry plantations highlighting the various management practices by giving emphasis on integrated pest management.

EVALUATION OF ENGLISH OAK ACORN VIABILITY BY X-RAY METHOD

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FDC: 181.525: 176.1 Quercus robur L.

The authors present the results of comparative research of acorn germination by means of standard germination method in sand, by quick method on filter paper, viability evaluation by TTC method and viability evaluation by x-ray method. The results show that the x-ray method provides accurate results in viability evaluation of recently collected English oak acorns and records all changes in morphological and physiological characteristics in the acorns x-rayed several months after the collection, due to loss of viability or presence of insects in the seed. The research should be continued by application of contrast x-ray method, which could supply additional information.

VEGETATIVE PROPAGATION OF ENGLISH OAK USING GRAFTING DEVICE

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FDC: 232.328.5: 176.1 *Quercus robur* L.

The importance of different vegetative propagation methods is increasing. Several methods are being used in improvement, genetics and ornamental horticulture. Those methods that can be used in practice are of special importance.

The paper describes a method of English oak (*Quercus robur* L.) device grafting, that can be used in practice for establishing clonal seed orchards and for propagation of ornamental trees (oaks with variegated leaves, oaks with pyramidal crowns and other cultivars).

The scions were cut from the donors age 200, 90, 60, 5 and 2 years. They were cut from the last year's and 2-3 year old twigs, carrying at least two buds. The root-stocks were two year old seedlings, and Ω-cuts were applied about 5cm above root necks.

Callusing was conducted by stratification in a mixture of saw-dust and moss (3:1), in a room with a stabilized temperature of 27 ^{0}C and 70-80 % humidity. After 14-20 days, 89 % of grafts callused, and 68 % flushed. Finally, after 54 days there was a total of 61 % stabilized, flushed, firmly joint grafts.

The age of donors and the part of twig used as scion had no influence as to the success of grafting.

WOUND-REGULATED GENE EXPRESSION IN HYBRID POPLARS

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FDC: 165.3: 44 + 453: 176.1 Populus L.

Trees have elaborate biochemical defenses against microbial pathogens and insect pests. These defense genes and their protein products may prove valuable for the application of biotechnology to tree improvement. Transcriptional control regions from tree defense genes could be fused to the protein-coding regions of useful genes recruited from other sources, such as the insecticidal endotoxin from *Bacillus thuringiensis* (BT). Transgenic trees expressing such a gene fusion would produce the BT toxin in proportion to the degree of insect damage, minimizing undesirable selection pressure against occasional or light grazers. The current practice of constitutive BT gene expression in transgenic plants mimics the indiscriminate use of chemical pesticides with its attendant problems; appropriate, damage-inducible transcription of the BT gene is analogous to selective spraying for pest control. The protein products of natural tree defense genes may themselves prove effective against pathogens and herbivores, either when produced at elevated levels in the source tree or when worthwhile defense genes are cloned and transferred from a "resistant" individual or species to a "sensitive" but otherwise desirable genotype. The longevity of trees implies that inherent defense mechanisms are quite sophisticated.

Fast-growing hybrid poplars (*Populus trichocarpa* x *P. deltoides*) accumulate a set of novel mRNAs in the upper leaves of trees whose lower leaves have been mechanically wounded. Many cDNAs corresponding to wound-responsive transcripts have been cloned and several have been sequenced. Some of these transcripts encode chitinases, which have been implicated in protection against pathogenic fungi and bacteria. Other accumulated mRNAs code for proteins related to Kunitz trypsin inhibitors; proteinase inhibitors deter insect feeding in some plants. The functions of other systemically wound-induced (*win*) poplar gene products are not known.

All poplar *win* genes examined so far are members of multigene families. Three distinct poplar chitinase gene families have been identified: *win4*, *win6*, and *win8*. At least two of the three families are organized into gene clusters, as determined by segregation of alleles in a three-generation pedigree. Genomic cloning, mapping, and sequencing reveal that *win6* chitinase genes are arranged in arrays of three or more, transcriptionally oriented in the same direction. *win4* chitinase genes are found embedded in the *win6* clusters, oriented identically.

Transcriptional promoters from several *win6* chitinase and *win3* proteinase inhibitor genes have been cloned, sequenced, and fused to *B-glucuronidase* (GUS). These *win*-GUS gene fusions have been introduced into tobacco to permit preliminary structural analysis of promoter function and physiological characterization of wound signal transduction in transgenic plants. *win*-BT gene fusions are being constructed to produce transgenic tobacco and poplar with facultative resistance to insect herbivory.

GROWTH, LEAF AREA AND DRY WEIGHT DISTRIBUTION OF POPLAR CLONES GROWN UNDER INTENSIVE CULTURE

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FDC: 181.6: 232.13: 176.1 Populus spp.

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Twelve clones of *Populus trichocarpa*, *P. deltoides* and their interspecific hybrids were grown under an intensive culture regime at a 1 m x 1 m spacing in a 0.36 ha plantation near Puyallup, Washington for four years (1985-1988). The entire study was part of a joint University of Washington / Washington State University Poplar Research Project, supported by the U.S. Department of Energy (Subcontract No. 19X-43382C with Oak Ridge National Laboratory).

Height, stem diameter and estimated stem volume were followed on permanent growth plot trees during the entire duration of the study. Above- and below-ground biomass and dry weight distribution were determined after harvest of the plantation at age four.

Five of the twelve clones (namely, two *P. trichocarpa*, one *P. deltoides* and two interspecific hybrids) were selected for more intensive physiological studies during the entire life time of the plantation. At the tree, branch and leaf level a number of physiological, morphological, structural and growth traits were studied on representative trees and in different replications. These characteristics are listed in the Table below and interrelationships among them as well as seasonal time courses will be discussed.

Year :	1985	1986	1987	1988
Age of plant material (yr)	1	2	3	4
Growth (height, diam., volume)	X	X	X	X
Phenology (bud burst, bud set)	X	X	X	
Biomass, dry weight distribution	X	X	X	X
Carbon allocation	X	X		
Leaf area index, light interception	X	X	X	X
Crown structure, branch orientation			X	
Branch characteristics (morphology)			X	
Taper and stem form traits			X	
Leaf orientation	X	X	X	
Leaf photosynthesis	X	X	(X)	

GENETIC CHARACTERIZATION OF SOME WHITE PINE SPECIES AND THEIR INTERSPECIFIC HYBRIDS BY ISOZYMES AND ITS POSSIBLE RELATIONSHIP TO BLISTER RUST RESISTANCE.

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FDC: 165.3: 174.7 *Pinus strobus* L.: 172.8 *Cronartium ribicola* J.C. Fisch

Eastern white pine, *Pinus strobus*, is a very important timber species. One method of achieving genetic improvement has been by interspecific hybridization with other white pines, especially in the breeding for resistance to white pine blister rust (*Cronartium ribicola*). Of importance for interspecific hybridization are *Pinus monticola*, *Pinus griffithii* and *Pinus peuce*. These species provide a wide range of genetic material and have varying resistance to white pine blister rust. *Pinus koraiensis* does not hybridize with the other species but is immune to white pine blister rust. A study of the genetic identification, variation and structure of these species is of great importance. With this information, a fuller knowledge of the evolutionary trend, inheritance pattern and a better utilization of the interspecific hybrids will be realized. In addition, identification of genetic markers highly correlated with traits such as blister rust resistance could be of great importance.

Isozyme analysis is used in this study. At least 20 individuals from each of the above-mentioned species and hybrid combinations have been selected. Needles and seeds of clones, fullsib and halfsib families (most of which have been tested for blister rust by artificial innoculation) have been collected and crude homogenates prepared. Electrophoretic procedures, using standard methods for starch gels, have been applied. Fifteen enzyme systems are being studied including malate dehydrogenase (MDH), shikimic dehydrogenase (SDH), glutamate oxaloacetate transaminase (GOT), peroxidase (PER), 6 phosphogluconate dehydrogenase (6 PGD), and phosphoglucose mutase (PGM). Data on the banding patterns of each individual has been collected and used in the analysis to determine parameters such as unique alleles, allele frequency, number of polymorphic loci and heterozygosity.

The study shows that all the species have unique isozymes and alleles for enzyme systems MDH, 6 PGD, PGM and PER which may be used for identifying the species and their hybrids. Species also differ in their allelic frequencies, number of polymorphic loci and heterozygosity for some enzyme systems. The values obtained for the proportion of polymorphic loci, average number of alleles per locus and average heterozygosity indicate that genetic variation within species is high.

SEED ORCHARDS IN ROMANIA

SUMMARY

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FDC: 232.311.3: (498)

In Romania the research on tree breeding by means of selection and crossing of plus trees and the establishment of seed orchards bega in 1959. The first clone seed orchard was established in 1961. At that time we started to carry out a national programme concerning the establishment of seed orchards consisting of introduced species (larch douglas fir, Scotch pine, black pine, Eastern white pine, red oak) for which the seed supply possibilities from domestic sources were reduced but there were sufficient valuable mature cultures of the same species in which plus trees of an exceptional level from the qualitative and quantitative point of view could be selected . Since 1976 the establis ment of seed orchards for all the important species became a main target of the Romanian silviculture.

During all these steps the achievement of seed orchards of the first generation was aimed at. When determining the seed orchard areas the purpose was not to cover the necessary seed amount for the nationa afforestation programmes only by seed produced in the seed orchards.

Until the end of 1988 a total seed orchard area of 1004.2 ha was established, out of which 575.4 ha of softwood trees (Norway spru fir, larch, douglas fir, black pine, Scotch pine, European white pine and stone pine) and 428.8 ha of hardwood trees (sycamore, cherry, whit lime, Quercus species, black locust, ash and eatable chestnut). 35.4 h of the total area were covered by seedling seed orchards consisting of half-sib and polycross and the rest by clone seed orchards. Interspeci hybridization seed orchards were also established (Larix decidua X L. leptolepis and the reverse combination). Most of them are provenance seed orchards consisting of plus tree families or clones selected in two or more provenance regions.

EFFECTS OF SIMULATED ACID THRUFALL ON FINE ROOTS, ECTOMYCORRHIZAE, MICROORGANISMS, AND INVERTEBRATES IN THE FLOOR OF SOUTHERN PINE FORESTS

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FDC: 425.3: 181.36: 114.6: 174.7 Pinus taeda L.: 174.7 Pinus palustris Mill.

A two-year study of the effects of natural and simulated acidic thrufall was initiated in March 1987. Rainfall, thrufall, and stemflow collectors were placed in a natural stand of loblolly pine (Pinus taeda L.) in south Mississippi and a 27-year-old longleaf pine (P. palustris Mill.) plantation in east Texas. The chemical composition of all thrufall collections and litter leachate was determined on samples taken during the week following each rainfall event. Thrufall was collected and acidified on site with nitric and sulfuric acid to pH 4.3 or 3.6. This solution was then applied periodically to m^2 plots (normal thrufall excluded) for one or two years. Control plots received non-adjusted thrufall. During the first year of the study, only the treated plots were covered with fiberglass thrufall exclusion shelters; control plots were also covered the second year. A randomized complete block design was used with ten blocks per study area; each block contained 3 treatment plots (control, pH 4.3, and pH 3.6). Five blocks at each site were excavated at the end of one and two treatment years. Chemical analysis of the soil layers from all plots was made at excavation each year.

The annual amount of thrufall applied in Mississippi was 968 mm (pH 4.69) and 905 mm (pH 4.45) during the first and second year, respectively; in Texas, the thrufall volumes were 646 mm (pH 5.12) and 701 (pH 5.10), respectively. In Mississippi, plots were treated 33 times during the first year and 32 times during the second; in Texas, the plots were treated 24 times each year.

Simulated acidic thrufall treatment had significant effects on root development (lateral root length and weight; total number feeder roots) and ectomycorrhizal development (total number ectomycorrhizae; percent ectomycorrhizae) at both sites. Most differences were significant after one treatment year; the effect was more pronounced after two years. Acidic treatment had little effect on microbial populations and nematodes. There were significant differences in the numbers of invertebrates on both sites due to treatment. After two treatment years, there were significant differences in mite populations. The Oribatids, Prostigmatids, and Astigmatids numbers increased with decreasing pH; predaceous Mesostigmata mites were less sensitive. Treatments decreased numbers of other groups of invertebrates, especially earthworms, but these were insignificant due to excessive variation.

These data indicate that the biotic processes of fine roots and soil within the forest floor of southern pine forests are very sensitive to slight increases in acid input. More studies are needed to determine how acid deposition affects these processes.

EFFECTS OF EXPERIMENTAL NITROGEN ADDITIONS TO SPRUCE ECOSYSTEMS IN THE BLACK FOREST (WEST GERMANY)

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FDC: 425.1: 425.3: 181.45: 181.34: 116.2: 174.7 *Picea abies* Karst: (430.1)

Two small forested watersheds at higher altitudes of the Black Forest were treated with 700 kg·ha^{-1} $(NH_4)_2SO_4$ in order to simulate elevated atmospheric depositions of nitrogen and sulfur. Applied amounts equal 150 kg·ha^{-1} NH_4^+-N and 170 kg·ha^{-1} SO_4^{2-}-S, respectively (10 to 15 times the annual atmospheric input of both elements). Furthermore, $(NH_4)_2SO_4$ is an agent with a high acidification potential. Proton load associated with the applied dosage can reach up to 21 kmol·ha^{-1} depending on N transformations in the soil, thus exceeding proton load by factor up to 50. The instrumental design allows for the assessment of manipulation effects simultaneously on the watershed and the ecosystem/plot level. Effects can also be studied in comparison to adjacent control watersheds/plots. The experimental watersheds are located in two contrasting study areas: Schluchsee (granite, well-drained podzols) and Villingen (Mesozoic quartz-sandstone, acid brown forest soils with tendency to waterlogging). Both areas are uniformly stocked with managed stands of planted Norway spruce (*Picea abies* (L.) Karst.). Due to differences in management history, the N turnover of the two sites differs considerably, even though N deposition is very similar. The Villingen site retains nitrogen nearly completely, whereas at Schluchsee, N output is in the order of the input. The paper presents and discusses initial effects of $(NH_4)_2SO_4$ application on the nutritional status of the stand and the chemistry of soil and water.

ÉVALUATION DES PRINCIPAUX POLLUANTS ATMOSPHÉRIQUES MESURÉS SUR LE BASSIN DU LAC CLAIR

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FDC: 181.45: (714)

Le bassin du lac Clair, situé à 50 km au nord-ouest de Québec, a été choisi pour l'établissement d'un site d'étude servant à l'évaluation de l'effet des différents stress environnementaux et, plus particulièrement, des polluants atmosphériques sur les écosystèmes forestiers. Cette région est dans le domaine climatique de l'érablière à bouleau jaune et reçoit des précipitations annuelles de l'ordre de 1 200 mm.

Une tour de 23 m de hauteur y a été érigée afin de procéder à la mesure des polluants atmosphériques au-dessus du couvert forestier. Les précipitations sont récoltées à l'aide de deux systèmes: un collecteur automatique et une entonnoir de 28,5 cm de diamètre. Les particules sèches sont captées à l'aide d'une pompe à haut débit qui aspire l'air à travers un filtre en téflon. En ce qui a trait aux polluants gazeux, l'air est aspiré à partir du sommet de la tour jusque dans une roulotte où différents appareils mesurent et enregistrent les concentrations d'ozone, d'oxydes d'azote et de dioxyde de soufre.

Depuis 1987, la mesure des polluants gazeux a donné des valeurs très près des limites de détection pour les composés d'azote et de soufre alors que l'ozone présente des teneurs de 30 ppb avec des pointes jusqu'à 110 ppb. L'évaluation des dépôts de particules sèches indique des concentrations moyennes de l'ordre de 0,29 $\mu g/m^3$.h en nitrate et de 3,58 $\mu g/m^3$.h en sulfate et des maximums de 2,0 $\mu g/m^3$.h en NO_3^- et de 20,0 $\mu g/m^3$.h en SO_4^{-2}. L'analyse par microscopie électronique de balayage et analyseur de rayons X par dispersion énergétique (MEB-EDAX) de poussières déposées dans des boîtes de Pétri a permis l'identification de gros agglomérats composés d'un coeur de silice sur lequel se déposent des cristaux dont les deux principaux constituants semblent être le soufre et le calcium.

Du point de vue des pluies incidentes, on retrouve pour l'été 1988 un pH moyen de l'ordre de 4,3 avec des pointes jusqu'à 3,45. L'acidité de ces événements est très fortement liée aux teneurs en sulfate et nitrate dissous.

Ces données indiquent la présence d'un stress environnemental sur l'écosystème forestier par les dépôts acidifiants.

FIRST RESULTS OF Quercus robur L. PROVENANCE EXPERIMENT IN CROATIA

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SUMMARY

FDC: 232.12: 176.1 Quercus robur L.: (497.1)

The first experiment of 16 different provenances of Quercus robur L. from Croatia was established in the nursery of Forest Research Institute in Jastrebarsko in Spring of 1986. Field experiment in four randomized blocks on two localities was laid out 1988. After 3 years of age (1988) the seedlings of "SPAČVA" provenance were the highest in average (39,48 cm at "Gajno" - locality and 37,12 cm - "Slavir" - locality). The smallest were the seedlings of provenance "GUŠEVAC" (31,15 cm at "Gajno" - locality) and provenance "Zdenački Gaj" (26,65 cm at "Slavir" locality). The survival varied from 86,00% ("LIPOVLJANI" "Gajno") to 99,75% (LIPOVLJANI - "Slavir" - locality).

HAYSCENTED FERN INTERFERENCE - A STRESS IN OBTAINING BLACK CHERRY REGENERATION

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FDC: 181.41: 231.1: 176.1 Prunus serotina Ehrh.: 173.5 Dennstaedtia Michx.

Hayscented fern (Dennstaedtia punctilobula Michx.), an important forest weed, interferes with establishment of advance regeneration of black cherry (Prunus serotina Ehrh.), a valuable tree species in the Allegheny hardwood forest of the northeastern United States. In shelterwood seed cut stands where ferns are not present, black cherry seedlings become established. When dense fern is present, black cherry seeds germinate, but do not survive long enough to become established and grow through the fern ground cover. A series of field, greenhouse and laboratory studies was conducted in shelterwood seed cut stands to learn the ecological and physiological basis of fern stress which prevents regeneration of black cherry.

Allelopathy is not the primary mode of interference between hayscented fern and black cherry. Neither foliage leachings nor root washings reduced seedling growth. There was no evidence for accumulation of allelochemical natural products in the soil. Nor was there evidence that allelochemicals interfered with infection of newly germinated seedlings by mycorrhizal fungi or with soil nitrogen transformations.

Competitive water uptake by hayscented fern did not interfere with black cherry seedling establishment. Gravimetric soil moisture measurements showed that moisture under ferns was less variable and often higher than that outside fern cover. Predawn and midday seedling water potential measurements were similar for seedlings growing inside and outside fern cover.

Competition for phosphorus, an important limiting soil nutrient, is not the primary mode of growth interference. Hayscented fern did not interfere with the speed or degree of mycorrhizal infection of young black cherry seedlings. Foliar phosphorus was just as deficient for seedlings growing with fern as without them.

Competition for nitrogen is a potentially important source of interference. Black cherry makes best growth when most nitrogen is supplied in the nitrate form. Presence of hayscented fern reduced the amount of soil nitrate- but not ammonium-nitrogen and changed the soil ammonium : nitrate ratio so that it was less favorable for black cherry growth. The amount of soil nitrogen is apparently sufficient to sustain black cherry seedlings, but change in the soil ammonium : nitrate ratio may influence black cherry seedling distribution.

Competition for light was the primary mode of interference. Hayscented fern reduced the photon fluence rate to less than 20 umols s^{-1} m^{-2} and the red : far-red ratio to 0.05. Black cherry seedlings survived poorly in this low photon fluence, high far-red environment. Restraining fern foliage behind a barrier which permitted a cone of light to reach black cherry seedlings resulted in high survival; growth was similar to areas with no fern.

SPECIES AND PROVENANCE SELECTION OF EUCALYPTUS FOR THE TROPICAL AND SUBTROPICAL PLANTATIONS IN CHINA

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FDC: 232.11/.12: 176.1 *Eucalyptus* spp.: (51)

Eucalypts have been grown in China for about 100 years. The total area of the eucalypt plantations in China is estimated to be about 400,000 ha, with the addition of 9,000 million individual trees planted around the four-sides.

Of more than 200 species introduced, only a few are used in commercial plantations, the main ones beijng *Eucalyptus exserta*, *E. citriodora* and *E. globulus*. Seed sources of the early introduction of eucalypts are largely unknown. In recent years, species and provenance trials have been established on a number of sites in southeastern, southern and southwestern China, some species and provenances appear very promising under the new environmental conditions.

Five geographical regions are proposed for developing plantation forestry with eucalypts in the tropical and subtropical areas of China based on the results from the species and provenance tests and bioclimatical analyses. The five divisions and species more suitable for each region are: (1) Southeastern area along the coast of East China Sea from Wenzhou to Santou; *E. grandis*, *E. saligna*, *E. camaldulensis*, *E. tereticornis*, *E. dunnii* *E. urophylla* and *E. maculata* for wood production; (2) Double G (Guangdong and Guangxi) region, *E. urophylla*, *E. camaldulensis*(northern form), *E.pellita* *E. tereticornis*(northen provenances), *E. cloeziana*, *E. grandis*, *E. resinifera* and *E. maculata* for pulp and construction; (3) Hainan Island and Leizhou Peninsula, *E. urophylla*, *E. camaldulensis*(northern), *E. tereticornis*(north), *E. brassiana* and *E. intermidia* for paper pulp and fuel; (4) Southwestern Plateau including Yunnan and conjunctive parts of Sichuan and Guizhou, *E. globulus*, *E. nitens*, *E. smithii*, *E. viminalis*, *E. camphora*, *E. radiata*, *E. divis* and probably a limited number species of Monocalyptus to produce wood and oils; (5) Inland areas in southern and central parts of China, there is great potential in planting around four-sides to produce small logs, fuel wood, oils and landscape beauty. There are a lot of species choices depending on local conditions.

HYBRIDIZATION OF *Acacia mangium* AND *Acacia auriculiformis*

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FDC: 165.41: 176.1 *Acacia mangium* Willd.: 176.1 *Acacia auriculiformis*

The reproductive biology of both *Acacia mangium* and *Acacia auriculiformis* were investigated. Both species are capable of self-pollinating, however cross-pollinating is much prefered. Comparatively, there are differences in the growth performance between the hybrids and seedlings of *Acacia mangium* and *Acacia auriculiformis*. The potential of using hybrids of *Acacia* in future plantations are discussed.

CLONAL DIFFERENCES IN SOLAR RADIATION CONVERSION EFFICIENCY OF CLOSELY SPACED POPLAR STANDS

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FDC: 161.32: 238: 537: 176.1 Populus spp.

SUMMARY

FDC: 161.32: 238: 537: 176.1 Populus spp.

Experimental stands of 5 poplar clones, Robusta, Fritzi Pauley, Columbia River, Beaupré and Raspalje were studied during their second growing season. Trees were planted in homogeneous blocks on a 0.80 m x 0.80 m spacing (15625 trees ha^{-1}) near Gent, Belgium (51°02' N, 3°39 E) and grown under intensive culture including drip irrigation, fertilization and weed control.

Interception of solar radiation by the closed canopies was measured using tube solarimeters for each of the five clones.

At regular intervals throughout the growing season (± every ten days) stem and branch dimensions (diameter and length) were measured as well as numbers of leaves, leaf dimensions and leaf orientation.

Stem and branch volume indices were transformed into wood dry weight using wood density data. Leaf area was calculated from leaf dimensions using allometric relations and leaf dry weight from the weight/area ratio.

Accumulated stem dry matter was linearly related to accumulated intercepted solar radiation. Seasonal average conversion efficiences for total above ground dry matter (stem, branches, leaves) were 0.72 g MJ^{-1} for Robusta and 1.10 for Beaupré.

Clones with high canopy energy conversion efficiency incorporated several better interesting structural variables (such as leaf area index, leaf area duration and leaf orientation) as well as superior photosynthetic traits (maximum leaf photosynthetic rates).

Leaf indices ranged from 6.0 for Fritzi Pauley to 9.4 for Beaupré. Extremes of leaf area duration were 568 for Robusta and 927 m^2 days m^{-2} for Beaupré. Solar radiation extinction coefficients (averaged over the growing season) were 0.23 for Beaupré and 0.37 for Fritzi Pauley.

Foliage area display and duration traits and superior photosynthetic performance are first order yield determinants for poplar under our experimental conditions. They are responsible for differences in above ground dry matter production that range from 9.9 t ha^{-1} yr^{-1} for Robusta to 15.3 t ha^{-1} yr^{-1} for Beaupré.

INSECTOS FORESTALES PERJUDICIALES EN LA ZONA CORDILLERANA ANDINO PATAGONICA DE ARGENTINA

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FDC: 453: (238.1)

The Andino Patagonian Forests are situated in the southern region of the Andes Mountain Range.

Some of its characteristics are described, together with the most important native forest species.

The damage-causing insects include: defoliators, seed insects, wood borers, bark borers, shoot borers, sap-sucking and timber insects.

The report covers entomological problems on native species and exotic conifers and hardwoods.

A STUDY OF BRUCHIDS DESTRUCTIVE TO THE SEEDS OF FOREST TREES (Bruchidae; Coleoptera; Insecta)

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FDC: 453: 416.2: 176.1: 145.7 Bruchidae

The family Bruchidae is almost exclusively associated with the family Leguminosae. Its members destroy the seeds of edible legumes such as beans, lentil, peas, grams and other pulses as well as the seeds of common legume trees. Nearly 90% of the bruchid fauna is associated with the wild legume trees and is responsible for serious damage to the seeds of such trees. The present day need of vigorous afforestation and the consequent requirement of the seedling is thus seriously hampered because of the shortage of healthy seed.

Extensive and intensive surveys during the last many years in the climatically diverse areas of India have revealed that about 50 species of bruchid attack as many species of forest legumes. The bruchid fauna largely comes from genus Bruchidius - but other genera like Caryedon, Conicobruchus, Spermophagus and Sulcobruchus are also fairly represented.

The main leguminous flora attacked by the bruchids belongs to genera, Acacia, Albizzia and Cassia. It is noticed that a majority of bruchid species are host specific and attack only one host plant while some have a broader host plant range. Likewise, many host trees are attacked by a single bruchid species while others are infested by a number of them.

Preliminary observations on the biology of a few selected species reveal an interesting correlation between host plant feeding and initiation of reproduction in the bruchids. Feeding by both the sexes on the pollen of the host plant seems to be an essential prerequisite for the maturation of gonads and subsequent copulation and oviposition. Some variations in respect of site of oviposition, mode of development and manner of emergence of adults have also come to light.

CAN SCIENTIFIC RESEARCH HELP SAVE WHITEBARK PINE FROM DISASTER?

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FDC: 174.7 *Pinus albicaulis* Engelm.: 4--01

Whitebark pine (*Pinus albicaulis* Engelm.) is a very important tree in the upper elevation forests of the Middle, Northern, and Canadian Rocky Mountains; the Sierra Nevada; the Cascades; and coastal ranges of British Columbia. Unfortunately, it is seriously impacted by a combination of: 1) successional changes to more tolerant tree species because of successful fire control, 2) the introduced blister rust fungus, *Cronartium ribicola* Fisch. ex Rabin., and 3) the native mountain beetle, *Dendroctonus ponderosae* Hopkins. Together these factors are decimating whitebark pine forests over much of its natural range.

What can research do to help save whitebark pine from disaster? We suggest: 1) develop the information to speed the natural selection and evolution for blister rust resistance, 2) provide a basis for returning fire to a natural role in mountain forests, thereby providing sites for regeneration, 3) provide the means to protect seed-bearing trees from mountain pine beetle, and 4) facilitate credible predictions on rates of climate change and potential sites where future management of whitebark pine is feasible. With regard to blister rust, our preliminary observations suggest that perhaps 1-2 percent of trees in high-risk stands may have natural resistance. We have begun studies to increase blister rust resistance, including establishing a natural tree seed orchard, propagating resistant scions onto faster growing white pines to shorten time until seed production, and testing of a technique for outplanting containerized seedlings pre-screened against blister rust. Other research at Intermountain Research Station focuses on seedling establishment, the role of fire in whitebark pine ecosystems, and the use of semiochemicals, such as Verbenone, to protect mature trees from bark beetles.

SELECTION OF WHITE WILLOW CLONES (Salix alba L.) SUITABLE FOR GROWING IN MIXED PLANTATIONS WITH BLACK ALDER (Alnus glutinosa L. Gaertn.)

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FDC: 228.0: 176.1 Salix alba L.: 176.1 Alnus glutinosa L. Gaertn

In a mixed plantation of black alder with 24 clones of white willow, black alder and white willow respectively were cut at plantation age 1+8. Out of 24 clones, 12 clones were cultivated without black alder. In this way the following treatments were formed: pure white willow, white willov and black alder, white willow - felled black alder, and black alder - felled white willow.

At plantation age 1+10, the largest production of stemwood dry matter has been established at the test plot of white willow with black alder (88.2 t/ha, control 73.10 t/ha). The production of stemwood dry matter in white willow at ages 9 and 10 has increased by 77% in relation to dry matter produced up to the 8th year. In some white willow clones positive modifications have occured in the production of wood mass under the influence of black alder. Black alder in association with white willow has a current increment of 6.03 m^3/ha (black alder - white willow felled 13.54 m^3/ha).

Dry matter content in the above-ground part of weed vegetation is highest in the treatment black alder - felled white willow (4.3 t/ha), and lowest in the treatment white willow with black alder (0.7 t/ha).

The effect of black alder on the chemical soil properties is reflected in higher organic matter content, higher concentration of total N and hydrolising N, and the increase of acidity. Concentrations of N are higher in the leaves of black alder than in those of white willow. White willow leaves contain relatively more Ca, S, Mg. Weed vegetation intensely accumulates Fe and this is particularly conspicuous in the treatment black alder - felled white willow, where the increase of acidity is highest.

The results indicate that there are possibilities for high intermediate yield of white willow and cultivation of black alder as the principal crop. Black alder can be also grown as coppice wood in the second vegetative generation.

Selection of white willow clones has been done on the basis of stem wood mass production, positive modifications in the wood mass production and the quality of stemwood.

LESSIVAGE DES CATIONS BASIQUES ASSOCIÉ AUX POLLUANTS ATMOSPHÉRIQUES DANS UNE ÉRABLIÈRE À BOULEAU JAUNE

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FDC: 425.1: 425.3: 181.45: 114.2: 176.1 *Acer saccharum* Marsh: (714)

Le Québec, de part sa situation géographique, est aux prises avec un grave problème environnemental: le dépérissement des forêts. C'est pourquoi le bassin du lac Clair, situé à environ 50 km au nord-ouest de Québec, a été sélectionné afin d'étudier les effets des polluants atmosphériques sur les écosystèmes forestiers.

À cette fin, nous avons installé des collecteurs sous couvert forestier et dans le sol à l'intérieur d'une place d'étude de 0,5 ha afin de mesurer les changements physico-chimiques des précipitations à différents niveaux dans l'écosystème.

Le lendemain de chaque événement pluvieux important (> 5 mm), nous mesurons la quantité d'eau récoltée dans chacun des collecteurs et nous préparons une bouteille de 250 ml afin d'analyser les paramètres suivants: pH, conductivité, alcalinité, Cl^-, NO_2^-, NO_3^-, SO_4^{-2}, NH_4^+, Na, K, Ca, Mg, Fe, Mn et Al.

Le niveau d'acidité des précipitations recueillies sous la couverture végétale est nettement moins élevé que celui des précipitations incidentes, ce qui indique une neutralisation partielle de ces dernières lorsqu'elles entrent en contact avec la cime des arbres. Cette neutralisation de l'acidité se fait au détriment des cations basiques comme le potassium, le calcium et le magnésium qui sont directement lessivés de la couverture végétale. Cependant, une partie de ce lessivage peut être attribuable aux particules sèches de cations basiques qui s'accumulent à la surface des feuilles pour être par la suite entraînées par les pluies incidentes.

Au niveau du sol, nous observons les deux phénomènes suivants: sous la matière organique, l'eau recueillie est caractérisée par une concentration plus élevée en nitrate, en calcium, en magnésium et en potassium. Le niveau d'acidité augmente également à cause de la contribution des acides organiques, résultat de la minéralisation de la matière organique. Dans les horizons minéraux, le pH de l'eau du sol augmente avec la profondeur. L'anion dominant est le sulfate alors que les cations dominants sont le calcium, l'aluminium et le magnésium.

Finalement, l'analyse foliaire d'érables à sucre échantillonnés à la fin juillet nous révèle que les concentrations de calcium et de magnésium sont nettement inférieures aux normes minimales requises et sont associées à un dépérissement de l'ordre de 25% qui sévit actuellement dans l'érablière à l'étude.

THE QUÉBEC FERTILIZATION APPROACH FOR CONTAINERIZED SEEDLING PRODUCTION

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FDC: 232.322.4: 232.329.6

Consideration of nutritional aspects for containerized seedling production should be a constant preoccupation of the nurserymen. They have to elaborate a fertilization schedule adapted to the seedling species and age and which must be adjusted to the seedling phenological stages.

In Québec, fertilization of container-grown seedlings is carried out to satisfy the weekly growth requirements of each species by maintaining an appropriate seedling tissue nutrient concentration and to keep a suitable substrate fertility.

Calculation of the weekly fertilization is made in two steps. Firstly, the weekly growth requirements of seedlings are calculated to maintain an appropriate nutrient concentration in seedlings. These requirements are obtained by multiplying the weekly increase of seedling dry weight by an appropriate tissue nutrient concentration. Secondly, a calculation is done to adjust and maintain the substrate fertility to a suitable level in function of the growing period.

The authors will talk about how to maintain substrate fertility in relation with the phenology and age of seedlings. They will discuss the variation of seedling tissue nutrient concentration in function of seedling dry weight. A calculation example of weekly growth requirements of black spruce 2+0 will be presented as well as the elaboration of its potential fertilization schedule.

THE EFFECTS OF WITCHES' BROOM ON PHOTOSYNTHESIS AND PLANT HORMONES OF MAKINO BAMBOO

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FDC: 416.17: 161.32: 161.4: 175.2 Phyllostachys makinoi Hay.

Witches' broom disease has caused severe damages to Makino bamboo (*Phyllostachys makinoi* Hay.) forest in Taiwan. It reduced terminal growth of bamboo culms, decreased yield of bamboo shoots, and deteriorated qualities of bamboo culms and shoots.

The causal pathogen is *Aciculosporium take* Miyake. It induced abnormal proliferation on the tips of secondary branches and twigs. Adventitious buds produced new shoots and foliages, forming a clustering of branches into witches' broom. White stromata developed on the tips of proliferated branches in early February. The leaf area of diseased bamboo was only 2.6% that of the healthy bamboo. There were significant differences in leaf proteins between healthy and diseased Makino bamboo. The diseased ones had five protein bands corresponding to molecular weight greater than 94K as analyzed with polyacrylamide gel electrophoresis. These five proteins were not present in leaves of the healthy ones. Quantitative analysis revealed that the amount of protein in leaves of the diseased bamboo was about 1.7 times that of the healthy ones. The yield of bamboo shoots in the infected bamboo forest decreased as much as 82%. There were also significant differences in isozymes, i.e., acid phosphatase, esterase, glutamate oxalacetate transaminase, and peroxidase, between leaf extracts of healthy and diseased Makino bamboos.

There was significant difference in rates of net photosynthesis between leaves of healthy and diseased bamboos. The rate of net photosynthesis of leaves of healthy bamboos was 15.32 mg $CO_2 \cdot dm^{-2} \cdot h^{-1}$ in average. However, it was only 2.53 mg $CO_2 \cdot dm^{-2} \cdot h^{-1}$ in leaves of the diseased ones. High gibberellin and IAA activity was found in the extract of diseased leaves at the infection stage. Gibberellin and IAA activity decreased to a low level at the proliferation stage. At the same time, total cytokinin activity increased in the extract of diseased leaves, reaching a maximum level at the late proliferation stage. There were significant increases in cytokinin activity induced by the infection compared with the healthy Makino bamboo. The cytokinin activity of leaves of diseased bamboo was approximately twice that of the healthy ones. The cytokinin concentration of leaves of witches'-broom infected Makino bamboo was estimated at about 0.74 $ug \cdot g^{-1}$ fresh weight. Cytokinin activity of leaf extracts was also demonstrated by tracheid formation in the lettuce parenchyma bioassay.

NITROGEN FIXATION AND PHOTOSYNTHESIS IN NATURAL STANDS OF *MYRICA ADENOPHORA* VAR. *KUSANOI*

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FDC: 161.38: 161.32: 176.1 Myrica adenophora var. kusanoi

Henchun bayberry (*Myrica adenophora* var. *kusanoi*), which possesses symbiotic nitrogen-fixation actinorhiza, can fix nitrogen symbiotically with *Frankia*. Henchun bayberry is an indigenous, and effective pioneer species distributed from 20 to 500 m altitude along seashore hills, grasslands, and mountain areas in Taiwan. This research was focused on the study of actinorhizal root nodule biomass, ultrastructure, nitrogen fixation, and photosynthesis in 3-year-old natural stands of Henchun bayberry. Ultrastructure of actinorhizal root nodule was studied with the scanning electron microscope and transmission electron microscope. Acetylene reduction assay and gas chromatography were used to measure nitrogen fixation activity. Photosynthetic activity was detected in the stands with portable photosynthesis system.

The results revealed that the host cells contained vesicles and hyphae. There was significant difference ($p<0.05$) between monthly biomass of live and dead nodules. The annual mean of live root nodule biomass was 7.6 g/tree, with a maximum biomass of 12.4 g/tree in July, and a minimum biomass of 2.7 g/tree in December. The dead root nodule biomass attained its annual mean of 0.7 g/tree, with a maximum of 5.6 g/tree in December, and a minimum of 0.6 g/tree in July and August. Annual mean of nitrogen fixation activity was 10.7 μmoles C_2H_4/g dry nodules/hr. Maximum rate of nitrogen fixation was 25.3 μmoles C_2H_4/g dry nodules/hr in July. Minimum rate of fixation was 0.6 μmoles C_2H_4/g dry nodules/hr in December. Total nitrogen fixation averaged 6.6 g N/tree. The average stand density was 3,820 trees/ha. The annual nitrogen fixation in natural stands of Henchun bayberry was estimated at 25 kg/ha. The average rate of net photosynthesis was 9.6 mg $CO_2.dm^{-2}.hr^{-1}$. The maximum rate of photosynthesis was 25.6 mg $CO_2 \cdot dm^{-2} \cdot hr^{-1}$ in July. However, the minimum rate of photosynthesis was 7.5 mg $CO_2 \cdot dm^{-2}.hr^{-1}$ in January.

Three-years' trials for Hylobius control and new concepts in the management of this pest in France, 1987 - 1989.

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ABSTRACT

FDC: 414.26: 145.7 Hylobius abietis

Hylobius abietis the large Pine Weevil is known in Europe to be the major pest of reafforestation sites of young conifers. Until recently, methods for limiting the damage of the insect were based on the dipping and spraying of plants with organochlorine or pyrethroid insecticides, providing less than the required period of control and sometimes undesirable effects on both the user and the environment.

In 1987, a series of bioassays and field trials was started in France (Limousin) with a new formulation of the carbamate systemic insecticide Carbosulfan provided by the Australian firm Incitec International. This new formulation, based on a controlled release technology gives protection over the critical period of two years when the plant is highly susceptible to Hylobius attacks.

The majority of field experiments were carried out with bare-root Douglas fir plants. In 1988 and 1989, we laid down trials using Norway spruce, Corsican Pine and Silver Fir in different regions (10 sites in the Limousin, 2 in the Auvergne, 4 in the Morvan, 2 in Brittany, 1 in Normandy, 1 in the Alps, 1 in the Ardeche) and also using containerized plants at some sites.

The first results show a good protection of the young plants (80 to 100% of tree survival) after a period of 6 to 30 months after treatment at planting time with 8 to 10 g of granules per plant (0.8 to 1.0 g of a.i. per plant).

This long term effect of the insecticide was confirmed in most of the sites where heavy Hylobius population pressure occured.

At the same time, the uptake of the molecule in the plant was recorded by gas chromatography of samples regularly collected from field sites.

The analyses also confirmed that a period of 7 to 10 days is necessary before a minimum dose of insecticide is present to preserve the plant and that concentrations of chemical can be maintained in the plant for a period up to 24 months.

In both ecological and economical aspects, this new control method leads to a better and safer protection of the plant, the environment and the user.

SEED SOURCE TRIALS OF *Eucalyptus grandis* IN ARGENTINA

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FDC: 232.12: 176.1 *Eucalyptus grandis*: (82)

E. grandis trees from seed sources from Australia, South Africa, Zimbabwe and Argentina were planted at two locations in the Mesopotamia Argentina. At age 5.5 years, significant differences in growth were detected among seed sources. Considering growth rate, seed sources from South Africa and southeastern Queensland and New South Wales in Australia, were considered good choices for planting in subtropical areas of the Mesopotamia Argentina.

PHENOLOGICAL STUDY OF *EPILOBIUM AUGUSTIFOLIUM* AS AN INDICATOR OF *PICEA GLAUCA* SEED MATURITY

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FDC: 181.8: 176.1 *Epilobium angustifolium* L.: [illegible]31.522: 232.312.1: 174.7

Picea glauca Voss

Successful cone collection of white spruce depends on our capacity to know enough in advance seed maturity to plan efficiently harvesting operation. Most indicators developed up to now (i.e. relative length of embryo, cone specific gravity and moisture content, etc.) forecast with difficutly the moment of cone collection.

In their investigations, the authors wanted to identify a phenological stage of development of an associated plant species which would be well synchronized with white spruce seed maturation. Fireweed was selected among many boreal plants for three reasons. First one, the floral pattern of this species follows the heat-sum of degree-days like seed growth of white spruce. Second, it is possible to find fireweed near every collection stand because it is an ubiquitous species in Québec. Finally, its inflorescence develops rapidly during the maturation period of white spruce seed. The inflorescence was divided in three parts to predict more precisely their phenological stages. Each of those sections progresses successively from the basis to the top with a delay of one week. Consequently, a specific stage of development of each section of the floral axis can be related with the progression of white spruce seed maturity.

Weekly harvests, in five different stations throughout the distribution of white spruce in Québec, have shown a good correlation between the time of white spruce seed maturation and the beginning of capsule bursting at the basis of fireweed inflorescence. This phenological stage corresponds to 1 350 ± 45°C degree-days and 2 100 thermal units. Therefore, it is possible to forecast, 1 or 2 weeks in advance, the time of cone collection by monitoring the acropetal progression of the floral axis of fireweed.

EFFECT OF WATER STRESS ON ETHYLENE PRODUCTION AND CHLOROPHYLL CONCENTRATION BY TWO *Eucalyptus* CLONES

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FDC: 232: 13: 181.31: 161.3: 176.1 *Eucalyptus grandis* Hill

This study was conducted to investigate the effects of water stress on production of ethylene and chlorophyll by clones of *Eucalyptus grandis* Hill hybrids. Seven-month-old plantlets of the clone 2814 of *Eucalyptus grandis* Hill x *Eucalyptus camaldulensis* Dehnh. hybrid and of the clone 2798 of *Eucalyptus grandis* Hill x *Eucalyptus robusta* Sm. hybrid were exposed to sublethal water stress while a control group of plantlets was kept well watered. Water potential was sampled with a pressure chamber and stomatal conductance with a steady-state porometer. Leaf content of ethylene was quantified with gas-liquid chromatography. Chlorophyll concentration was determined spectrophotometrically of acetone leaf extract. Ethylene production rates and chlorophyll concentration in leaves from the clones increased slightly with initial stress, then decreased with decreasing water potential. Correlation between stomatal closure and the rate of ethylene production was found. However the decrease of ethylene as water stress increased suggests that ethylene is not involved in the maintenance of stomatal closure. Positive relationship between ethylene and chlorophyll concentration is discussed. The initial increase of chlorophyll production in response to drought stress may allow the plant to maintain photosynthesis under reduced gas exchange. Differences in the response to water stress occurred between seed sources. Plants of clone 2798 were better adapted to drier environments than those of clone 2814 because of greater root biomass and of an earlier closure of stomata.

PHENOLOGICAL RELATIONS OF THE PESTS ASSOCIATED WITH SAXAUL PLANT IN ABARDEG AREA

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FDC: 181.1: 176.1 *Haloxylon ammodendron* Bgc.: 453

Located 40 km. South East of Tehran, Abardeg Sand Stabilization Station have dry hot summer and moderately cold winter. Average annual precipitation is 135 mm (nine year average) and temp. around 16.5. ^{o}C So far more than 5000,000 hectares of sand covered lands, have been rehabilitated.

Haloxylon ammodendron is one of the main species successfully used in sand dune stabilization programmes throughout the country. The objective of this study was to examine the composition and structure of the pests at different phenological phases of saxaul plants. Eight phenological phases of saxaul plants.

Eight phenological stages have been recognized over the entire growing season which begins with emerging out from winter dormancy followed by flower buds appearance; full flowering; fruit setting seed ripening; duration of seeds on the plant; defoliation period and winter dormancy initiation. Each phases have carefully investigatet and the emerging time as well as the abundance of different pest species associated with saxaul plants monitored and the data recorded in specially-designed tables.

In the begining phase which occur as mid-Feb. to early Apr.,saxaul plants are sabject to attack by two gall-producing flies of *Cecidomyidae* family as well as three species of gall mites of *Eriophyidae* and *Tenuipalpidae* families and also saxaul thrips. Following stages which include emergance of bads and flowers as well as full flowering to fruit setting which constitute the critical periods of plant life and occur as early Apr. to late Sep.,comprise activity of such pests as aphids; julodis beetle; saxaul weevil, grasshopper (*Dericorys albidula*); white scale, and toree of mouse species.

And finally, fruit setting and seed ripening periods occur as late as Sep. through mid- Nov., during which Haloxylon plant is subject to damage by *Proceratia casariella*, which is a serious pest feeding on seeds. In general, based on gathered data, Haloxylon plants are now subject to attack and damage by sixteen distinct pest species of eleven familie.

ESTIMATION OF PRODUCTIVITY IN PINUS PINASTER PLANTATIONS IN CENTRAL SPAIN

ESTIMACION DE LA PRODUCTIVIDAD ENREPUBLACIGNES DE PINUS PINASTER EN CENTRO DE ESPANA/

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FDC: 242: 174.7 *Pinus pinaster* Ait.: (46)

Thinning with different internsities have been carried out on a 33 years old *Pinus pinaster* plantation and results have been compared with that of witness treatment. The experimental design consists of randomized blocks. Standing biomass before thinning biomass removed with thinning and standing biomass after thinning have been estimated torough inventories and subsequent determination of modular values. Litterfall represented by leaf fall and dead branches has been measured as well as its evolution throughout the year on plots representing vour different stand densities. The evolution of diameter growth has been sutdied as well for each stand density. Timber yield has been measured and compared with branch and leaf yields.

DIFFERENTIATION AT THE GENE POOL AND GENOTYPIC LEVEL WITHIN AND BETWEEN POPULATIONS OF *Pinus leucodermis* Ant.

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FDC: 165.3: 174.7 Pinus leucodermis Ant.: (45)

Pinus leucodermis Ant. is a relic endangered species with a discontinuous and restricted distribution: in Italy it occurs in only four small groups of populations located in the South: its genetic resources have been analysed both because they need to be conserved and because the species could be utilized for reforestation programs, as it has a great adaptability to extreme environmental conditions. Five populations have been sampled: from 17 to 30 trees per population have been genotyped by means of isoenzyme electrophoresis. 13 enzyme systems have been analyzed, coded by 23 gene loci.

The gene pool differentiation within populations, as measured by the δ_T value, which in a first approximation corresponds to the so called expected heterozygosity, is lower than that usually found in coniferous tree populations and varies quite widely between populations: this could perhaps be due to reductions in the population size that were suffered by the species in the past. The gene pool differentiation between populations is quite low, as the value is 0.058: nevertheless, there are interesting differences in the distribution of some rare alleles at some loci between the five populations, which could be of great importance for the conservation of the genetic resources of the species. The differentiation at the genotypic level is greater than that at the gene pool level and the corresponding δ value is 0.111: there are marked differences in the genotypic distribution both between loci and between populations. At some loci, namely ACO-A, PGM-A, 6PGD-B and PGI-B, a constant trend can be observed, with three of the populations showing low values of conditional heterozygosity and the remaining two much higher values: this allows the distinction of the five populations into groups and reflects perhaps different adaptational strategies due to different environmental conditions.

The implications of the results for the conservation policy of the species will be discussed in the light of the peculiar life-history, ecological and reproductive characteristics of the species.

SITE CHARACTERISTICS AS BASIS TO ESTIMATE THE VULNERABILITY OF NORWAY SPRUCE STANDS TO *IPS TYPOGRAPHUS*

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FDC: 622: 174.7 Picea abies Karst.: 145.7 Ips typographus L.

The literature and precedent own research pointed out the great variability of the intensity of *I. typographus* attacks on Norway spruce (*Picea abies)* baited with pheromones. Studies were started on the relationships between those attacks and various characteristics of the trees or of the stands, to bring up a better view on the genetical or stand factors involved. and to be able to use them in an integrated control strategy against the bark beetles.

The aim of the present communication is to describe some possibilities of predicting the probable mean number of attacks of *I. typographus* in spruce stands on ground of physical or chemical characteristics of the trees and of the sites.

The basis data were obtained in 12 belgian spruce stands situated in ecologically very different areas. The study lasted on 3 flight seasons of the insect in 1987 and in 1988. In each stand. 10 trees are choosen at random. baited with Pheroprax®. and cut down 6 to 8 weeks later. The *Ips* attacks are then counted in bark samples, furnishing a quantitative estimation of the vulnerability of each tree. The mean value of those counts is used as estimator of the stand vulnerability, and the aim of the present research was to predict this value on the basis of external variables.

The following independent variables were retained: the altitude of the site, the circumference, the age, the growth speed of the trees, the mean distance between the trees, the soil humidity, the soil pH (H_2O) and pH (KCl), and the soil contents in C, N, K, P, Mg, Ca, Fe, Cu, Zn and Mn. We did also study the minerals and terpenes content of the bark, but this part of the research is not presented here.

The relations between Ns (the mean number of attacks per tree for a stand) and the independent variables were studied by stepwise regression analysises which furnished a.o. the following results:

Independent variables

Type	Entered variables	R^2	p	Equation
Soil chemistry	P,Fe,C/N	0.817	0.0025	Ns=26.3 -4.11P -0.084Fe +1.69C/N
Stand factors	Altit.,Circf.,M.Dist.	0.837	0.0016	Ns=60.78 -0.061Alt -0.415Circf +4.823M.Dist
Total	Altit.,N,C,Circf.	0.875	0.0028	Ns=72.29 -0.055Alt -78.59N +2.465C -0.196Circf

Graphical illustrations and complementary approaches shall be equally presented.

This study point thus out the possibility of obtaining a very good estimate of the expected number of *I. typographus* attacks in spruce stands on the only account of site characteristics. This model seems equally able to predict the effect of modifying those characteristics; f.i., the thinning, increasing the mean distance between trees, or fertilization, are susceptible to influence the risk of attacks by *Ips typographus*.

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* Recherches subsidiées par l'Institut pour l'Encouragement de la Recherche Scientifique dans l'Industrie et l'Agriculture (I.R.S.I.A.)

Benefits of Hybridisation for the Temperate Eucalypts

by

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FDC: 165.41: 176.1 Eucalyptus spp.: (212)

ABSTRACT

Eucalyptus globulus and E. nitens are important plantation species for temperate climates. Both species have operational limitations. By hybridization with other species, including grandis, gunnii, cordata and others, clones have been developed with increased frost resistance, easier production of cuttings and potentially better wood properties, whilst still retaining their general silvicultural characteristics. However, within each specific hybrid cross there is considerable variation and further development and selection is required.

VITESSE DE DECOMPOSITION DES RESIDUS VEGETAUX DANS LES ERABLIERES DU QUEBEC EN RELATION AVEC LE SOL ET LE DEPERISSEMENT DES ARBRES

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FDC: 424.7: 114.6: 176.1 Acer spp.: (714)

Au Québec, on observe depuis quelques années dans ~~les~~ sols, parallèlement à une augmentation du taux de sévérité du dépérissement des forêts, une diminution du pH et un appauvrissement en éléments nutritifs. Dans un tel contexte, il est permis de penser que le recyclage des éléments minéraux lors de la décomposition des litières par les organismes telluriques s'effectue plus lentement, modifiant de ce fait le cycle biogéochimique. C'est pourquoi une étude de la vitesse de décomposition des résidus végétaux qui tombent sur le sol est réalisée dans ce travail en tenant compte de la nature du sol et de la sévérité du dépérissement. La vitesse de décomposition des résidus végétaux (tiges et brindilles en moins), exprimée en valeur relative "I", est calculée de la façon suivante:

$$I = Lv - Lt - F \quad Ln \qquad (1)$$

Ln (feuilles récentes) représentant le poids sec de l'horizon Ln occupant une surface de terrain déterminée, Lv (feuilles anciennes : >1 an) et Lt (feuilles anciennes fragmentées) le poids sec des horizons Lv et Lt situés sous l'horizon Ln prélevé, et F le poids sec de l'horizon F situé sous les horizons L prélevés. L'échantillonnage est réalisé à l'automne, après la chute des feuilles.

Les résultats obtenus indiquent que, dans les érablières du Québec, "I" est inférieur à 1 lorsque les résidus végétaux sont décomposés rapidement, en général en moins de 2 ans. C'est le cas des sols d'érablières à mull développés sur roche-mère calcaire, dont la forte activité biologique est liée surtout aux microorganismes et aux vers de terre. Lorsque "I" est compris entre 1 et 3, il caractérise des sols d'érablières de type moder, dont l'activité biologique modérée est liée principalement aux Microorganismes, aux Micro-arthropodes et aux Enchytraeides: la décomposition s'effectue alors en 2, 3 ou 4 ans en moyenne. Lorsque "I" est compris entre 3 et 7, il caractérise généralement les sols imparfaitement à mal drainés de type mor ou mulls hydromorphes, retrouvés dans les faibles dépressions des érablières; l'activité biologique est faible et la vitesse de décomposition est lente (>4 ans). Et enfin, lorsque "I" est supérieur à 7, il caractérise généralement les sols très mal drainés, dont la décomposition est très lente (souvent >10 ans). Ces sols se retrouvent dans les dépressions importantes des érablières. Dans une érablière des Laurentides subdivisée en parcelles de 00 x 20 cm, la valeur moyenne de "I" des parcelles peu affectées par le dépérissement (taux de sévérité < 10%) est inférieure d'une unité au moins à celle des parcelles modérément affectées (taux de sévérité d'environ 25-30%).

ROOTING JUVENILE CUTTINGS OF FOREST TREES WITH THE "BOUTURATHÈQUE" SYSTEM

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FDC: 232.328.1: 232.329.6

Operational cutting production of forest trees is still a minor activity in nursery production but successful cutting programs with spruce species in Europe and in Canada have brought new interest in propagation techniques.

A new system was developed for rooting conifer and hardwood cuttings based on continuous culture of mother-plants in greenhouses allowing multiple cutting productions throughout the year. Rooting was performed under artificial conditions in confined containers covered with polyethylene or clear plastic lids and located in a temperature-controlled room. Containers were put on shelves lighted with fluorescent lamps. Succulent cuttings were left in the rooting containers for a 4 week- or 8 week-period for hardwood and conifer cuttings, respectively. Cuttings were rooted under low light intensity (30-50 $\mu mol.s^{-1}.m^{-2}$) with a temperature inside the container of 25°C. Cuttings were hand-misted 2 to 3 times a week. The first roots appeared after approximately 10 days for hardwood cuttings and 4 weeks for conifer. Rooting under controlled conditions was more reliable than using misting units in greenhouses where results are unpredictable and subject to seasonal variations.

Cuttings of black spruce, Norway spruce, white spruce, larch, poplar, alder, basswood, yellow birch, black cherry, and white ash were successfully rooted with the "bouturathèque" system. Rooting conditions were optimized by testing different lamps (Cool-white, Daylight, Gro-lux, Spectralite), light intensity (20-70 $\mu mol.s^{-1}.m^{-2}$), photoperiod (12-24 hrs), and misting frequency. The effects of auxin, mycorrhizal fungus, cutting size and position, and cutting stage of lignification were tested on rooting of conifer cuttings.

This technique of cutting propagation was recently adapted for operational production of 1 million stecklings a year.

Environmental Architecture - Preventing Loss of Seed Production by Insects in Black and White Spruce Seed Orchards, Y. H. Prévost, School of Forestry, Lakehead University, Thunder Bay, Ontario, P7B 5E1, (807) 343-8342.

FDC: 453: 416.2: 415: 232.311.3: 174.7 Picea mariana B.S.P.: 174.7 Picea glauca Voss

Most efforts at minimizing damage by cone and seed insects has been focused within the seed orchard, when orchardists are ultimately faced with preventing migration of cone and seed insects from the surrounding forest into the orchard. Environmental architecture which is the intentional modification of insect behaviour and insect physical environment through alteration of vegetation, is suggested as a control strategy for spruce budworm, *Choristoneura fumiferana* (Clem.), and spruce cone maggot, *Strobilomyia neanthracina* Michelsen, two damaging species of spruce cones. Environmental architecture stresses modification of the orchard surroundings to minimize this migration and should be incorporated into the planning for orchard establishment. A first approach is to establish orchards away from forests whose tree composition does not contain much spruce and balsam fir. This is not always possible, and in a second scenario the surrounding forests must be groomed to promote healthy trees, and spruce and balsam fir should be removed to prevent budworm and cone maggot from developing near the orchard. Furthermore, pollen dilution zones, 500 m clearcuts, should be established around orchards. This in itself will create a barrier for migrating insects. To increase the effectiveness of the zone, two rows of deciduous windbreaks should be planted. The windbreaks would serve to mask the orchard visually and by olfaction from insects originating in the forest. Also, it would physically filter insects being blown into the orchard and last, would interfere with local insect dispersal by generating turbulent air. Moreover, clearcuts coupled with windbreaks may be compatible with management of foreign pollen and prevention of seed orchard invasion by squirrels.

PROSPECTS OF YELLOWS TYPE OF DISEASES IN SOME INDIAN WOODY PLANTS:A REVIEW.

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ABSTRACT

FDC: 444/449: 176.1: (540)

A number of yellows type of diseases caused by virus and mycoplasma like organisms are reported to occur in India in many forest trees of economic importance. Sandal, eucalyptus,coconut are gift of natural resources and are considered to be the important source of revenue due to wood,aromatic oil, medicine, paper pulp produced from them. While eucalyptus (*E.terreticornis*, *E grandis*) and zizyphus (*Zizyphus mauritiana*) are predominent in the forest of all over India, sandal (*Santalum album*) and coconut (*Cocos nucifera*) are more common in the southern forest of Deccan India. However,these trees are prone to many important diseases which reduce their yield. The sandal wood and sandal oil is on the decline due to spike disease and thus ruining the once flourishing industry of the country. Sandal spike which is considered to be the most serious yellow type disease of forest trees and now known to be caused by MLO ,was first reported as early as 1899 by Mc Carthy from Coorg in Mysore.Mycoplasmal etilogy of spike was confirmed in 1969 by Dijkstra and Ie from Netherlands ,Hull & his coworkers from U.K. and Varma et al from India through electron microscopic studies .Further confirmation of MLO as the pathogen was obtained from its positive response to tetracycline therapy by Raychaudhuri et al in 1972. Three virus diseases namely,mosaic ,leaf crinkle and little leaf diseases of eucalyptus were reported by Sastri et al in 1971 from Karnataka. Later on it was reported on several trees of Haryana and Kerala. Based on the light microscopic and ultrastructural studies and remission of the disease symptoms by tetracycline therapy, it was confirmed by Kerala Forest Research Institute that mycoplasma like organisms are associated with little leaf of eucalyptus .

HEAVY METAL EFFECTS ON SOIL AND CERTAIN TREES OF AN INDUSTRIAL AREA IN HYDERABAD, INDIA.

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FDC: 425.1: 425.3: 181.45: (540)

SUMMARY

The paper makes a comparative account of soil properties with special reference to heavy metals in industrial and non industrial areas of Hyderabad. The study was carried out for an year at monthly intervals for the metal composition viz. Fe, Cu, Zn, Pb, Co, Ni, Cr, Mn. The heavy metal inputs to the soil are identified mostly due to emmissions from smelters, blast furnaces and heavy vehicular traffic. The heavy metal input got a wide spectrum in its accumulation patterns in soil, adsorption and absorption on foliar surfaces. Hence the study has been extended to correlete how far the aerial inputs of heavy metals into soil could bring about changes in soil properties and also on plants. Mn, Pb, Fe are formed in relatively high concentrations when compared to nonpolluted area. The accumulation of heavy metals has shown significant relation with changes in soil pH and organic matter. The foliar deposition is found higher in *Pithecolobium dulce* with 3.06 - 0.64 ppm while Cu was more in *Acacia*. Based on results the trees were classified as accumulator and response indicators of heavy metal pollution.

Keywords: Heavy metals, Absorption, Accumulator,
Response indicator.

INCIDENCE OF ENTOMOGENOUS FUNGI IN THE BAGWORM, *CREMATOPSYCHE PENDULLA* (PSYCHIDAE: LEPIDOPTERA) ATTACKING *ACACIA MANGIUM*

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FDC: 453: 176.1 *Acacia mangium* Willd.: 411.16: 145.7
Crematopsyche pendulla: (595)

The estimated shortfall of sawn timber in Peninsular Malaysia by the mid 1990's has, as a matter of urgency, seen the formulation of a concept of compensatory plantation forest. An area of 200 000 hectares will be planted over the next 15 years with fast growing exotic hardwoods with an estimated development of cost of $406.52 million ringgit. At the end of 1988, 30 000 hectares of natural forest in the Peninsular Malaysia has been cleared and planted largely with *Acacia mangium*.

A. mangium, a legume, is native to the eastern Indonesian archipelago, New Guinea a north-eastern Australia. Like many other exotic plants, *A. mangium* is also exposed to the risk of insect pests. One of the insects recently found attacking *A. mangium* trees is a polyphagous bagworm, *Crematopsyche pendulla* (Lepidoptera: Psychidae).

C. pendulla is a pest of oil palm and a potential pest of the newly introduced plantation forest species, *A. mangium*. Heretofore no information on the entomogenous fungi associated with this bagworm was available. In this study, bagworms were sampled monthly over a period of six months. Distribution of infected bagworms, pathogens involved and pathogenicity of isolated fungi were determined and evaluated. The result of the survey showed that fungal diseases contributed a monthly mortality of 2% and 18% in the larval and pupal population of the bagworm, respectively. There was a significant relationship between diseases incidence and density host population ($r = 0.82$) and also disease incidence and rainfall ($r = 0.81$). Stratification in the disease incidence did occur among the pupal population. High proportion of infected bagworms was found at the bottom stratum of the tree. Six species, pathogenic and saprophytic fungi, namely *Paccilomyces fumosorosous*, *Fusarium* sp, *Pestalotiopsis* sp., *Aspergillus flavus* and *Syncephalustrum racomonsum* were isolated from the field collected bagworms. *P. fumosoroscus*, the most frequently isolated fungus, proved to be pathogenic to the bagworm.

INDIVIDUAL RESISTANCE OF OAK PEDUNCULATE (Quercus robur L.) TO DEFOLIATING INSECT Euproctis chrysorrhoea L. IN NORTH-WEST ROMANIA

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FDC: 453: 416.11: 165.3: 176.1 Quercus robur L.: 145.7
Euproctis chrysorrhoea L.

Our research works regarding relationships batween host plant (Quercus robur) - insect pest (E. chrysorrhoea) were carried out during the years 1985 - 1987, but in the years 1975 and 1977 we had already carried out experiments on the influence of the food quality in the development of the caterpillars (SCUTAREANU,1980) bringing out this phenomenon. Since 1988 we have been getting into the causes and mechanism of natural resistance of the oak pedunculate trees to the potential attack of E. chrysorrhoea (Lepidoptera, Lymantriidae) an important defoliator in northwestern and western parts of Romania.

Chemical analyses on the leaf samples picked up at 4-5 instances during caterpillar development from trees selected previously during outbreaks, in four forests, we determined the content in defence substances, organic nutrients and minerals, as well as mineral substances and acidity (pH) in the soil under the trees. Field rearing of E. chrysorrhoea caterpillars was accomplished in order to test the resistance. Biometric assessments have led to the discovery of specific phenotypic features of the resistant trees with a view to recognising them between outbreaks of the pest and to promote them in the composition of the stands as a preventative measure in integrated control.

The following results may be mentioned:

The phlavonoids and total polyphenols, the main toxic substances for caterpillars, always have double values in the resistant tree leaves as compared to unresistant trees, the first being higher in the mature and the second in the younger leaves. Organic acids (succinic, citric, tartaric, malic, quinic) also have higher values in the resistant tree leaves, increasing from younger to mature leaves. Tannin too is sometimes higher in the younger leaves. Lignin presents some exceptions but the values are always higher in the mature leaves. Essential aminoacids (valine, histidine, tryptophane) have higher values in the unresistant trees, while the unessentials (lisine, arginine, tirosine) do in the resistant trees. Total proteins and nitrogen have variable values, usually higher in the resistant trees, but monosugars in the unresistant trees. In the soil the acidity is higher under the resistant trees. Phenotypically, the resistant trees have generally thinner branches, their insert in the stem smaller than 45° on average, rhytidom thinner and having superficial - medium deep cracks, longer leaves on average than the unresistant trees. Medium percentage of the resistant trees (undefoliated, or defoliation less than 10%) is 21.3% on average in 35-60 year old stands of Querceta roboris rubosa. Finally, from the caterpillers fed on leaves from resistant trees we obtained pupa lighter than those fed on leaves from unresistant trees.

THE *in vivo* CHLOROPHYLL FLUORESCENCE INDUCTION CURVE — A USEFUL INDICATOR OF TREE PHOTOSYNTHETIC POTENTIAL

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FDC: 161.32: 181.31

After a necessary period in dark the leaf sample exposed to 670 nm monochromatic light produces in about 60 sec a *in vivo* chlorophyll fluoresvence induction curve (CFIC) with the main parameters: original (O), peak (P) and terminal (T) fluorescence intensities. The P-O (variable fluorescence) theoretically can be used as an indicator of photosynthetic potential and it is much easier to be measured than net photosynthetic rate (NPR).

To study the relationship between CFIC and NPR a series of experiments was made with rooted cuttings of *Populus euramericana* I-69 grown in the potted soil (light loam) with the water content of 6%(v/v) (-1.2 MPa), 9% (-0.38 MPa) and 12% (-0.14 MPa). The NPR and the CFIC were measured with Li-6200 Portable Photosynthesis System (LI-COR Inc.) and SF-30 Plant Productivity Fluorometer (Richard Brancker Research Ltd.) respectively.

Soil water content (%)	Photo. active radiation (umol/m^2/s)	NPR (umol/m^2/s)	Stomatal resist. (s/cm)	O in CFIC (arbit unit)	P in CFIC (arbit unit)	$\frac{P-O}{O}$	$\frac{P-O}{NPR}$
	9:30 a.m.						
12	1250	12.97	0.4372	3709	6643	0.79	226
9		10.94	0.5081	3639	6250	0.75	251
6		3.56	1.1286	3499	6012	0.71	705
	3:30 p.m.						
12	1600	10.67	0.6335	3962	6723	0.73	249
9		7.43	1.0164	3816	6439	0.68	331
6		0.67	1.8340	3743	5891	0.57	3034

According to our experiments the O and P values in CFIC all declined with water stress. The P-O / O (the ratio of variable fluorescence to constant one) which implied the photosynthetic potential was also diminishing with the decrease of soil water content. However, the P-O / NPR which implied to certain extent the photosynthetic quantum requirement seriously increased with water stress, particularly in the afternoon. It is suggested that the CFIC measurement is a very useful tool in tree photosynthesis research.

INDUCED CALCIUM DEFICIENCY SYNDROME IN FORESTS AFFECTED BY ACID DEPOSITION

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FDC: 425.1: 425.3: 181.45: 181.34

A high calcium requirement for adult trees has long been known as a major difference between trees and crop plants. Unlike other major essential elements (N,P,K), calcium is not recovered from mature living sapwood as it is converted to a non-living heartwood core in the stem of forest trees. Calcium remains sequestered in wood until it decays. It is from the decaying organic layer of the forest floor that most calcium and magnesium is made available to forest trees. Small inputs from the atmosphere and from mineral soil make up leaching losses in a balanced ecosystem. However, evidence from several sources indicates that an accelerated loss of calcium has accompanied increased pulses of strong acid anions entering the forest ecosystem as the result of acid deposition, an undesirable by-product of 20th century economic development. During early stages of acid deposition, exchangeable calcium and magnesium are mobilized producing a "fertilizer effect", as well as accelerated leaching. However, this positive effect is followed by "induced deficiency" as essential divalent cations, calcium and magnesium, are brought into the same range of concentration as trivalent cations, aluminum and iron, which have also been mobilized by increasing acidity and ionic strength. At equivalent concentrations, aluminum and iron suppress the uptake of calcium and magnesium. Suppressed uptake of essential cations is followed by suppressed growth of tree meristems. Prolonged growth suppression leads to loss of tree defenses against endemic abiotic factors and biotic agents. Thus, widespread death of spruce and fir in northern forest ecosystems can be linked to acid deposition through interactions with exchangeable base metals in the rooting zone of adult trees.

SEASONAL CHANGES IN THE SULPHATE CONTENT OF SOILS EXPOSED TO ATMOSPHERIC POLLUTION

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FDC: 425.1: 425.3: 114.1/.2

SUMMARY

Deposition of atmospheric sulphur in the soils has the influence on the mobility of sulphate and leaching of the ions which is potentially important during the cycling of sulphur. Seasonal changes in soil PH sulphate concentrations were measured in two brown earth soils; one provenance studied was exposed to severe industries while the other provenance was relatively unpolluted. In the heavily polluted site the soil PH was relatively lower than the unpolluted soils; except during September, and the peak levels of sulphate concentrations were during summer and autumn seasons. Various physico-chemical characters of soils like moisture content, organic matter, electrical conductivity, chlorides, Bicarbonates, Total nitrogen, phosphorous, potassium and organic carbon were analysed and the relationships were drawn with that of the sulphate contents of soil and that of the ambient sulphation rates.

Keywords: Atmospheric pollution, soil, sulphate content

REFLECTIONS ON BIOLOGICAL CONTROL OF FOREST INSECT PESTS

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FDC: 453: 411

Used and success of biological methods of control of forest insect pests depend upon an accurate estimation of research results conducted over vast forest territories. This estimation should consider the limits of efficiency and long-term profit into which a given predator, parasite or entomopathogenic microorganism might be useful for the protection of the forest and its part in the environment. Thus, in order to use the beneficial complex of nature, it is essential to deeply analyse the main characteristics of a forest at a time when insect pest population reach an endemic or an epidemic level.

These are good examples of regulation of insect populations by predators (ants, coccinellidae, etc.) and parasites (Tachinidae, Hymenoptera, fungi), but apparently these cannot be used in the forest as control agents during an epidemic. In addition, viruses have been used for the control of some Tenthredinidae and Bacillus thuringiensis for the control of certain Lepidoptera and may prove to be as efficient as chemical insecticides. Also, dissemination of virus or protozoa infected insects offers possibilities for the regulation of forest insect pests.

During the course of our work, we have demonstrated the aerial application of a concentrated virus suspension for the control for the Tenthredinid Neodiprion swainei Midd, and B. thuringiensis for the control of the Tortricid Choristoneura fumiferana Clem. gave promising results and may lead to the eventual replacement of chemical insecticides now used for the control of these insects.

Also, if the current use of a virus is sometimes difficult, the preparation of virus stock being only feasible on living insects, the use of B. thuringiensis is made easier as the bacillus can be produced commercially.

Also, to determine the present and future of forest insect populations we developed and used a biochemical forecast method based on the determination of the variations of certain metbolites and of the activity of certain enzymes in these insects.

To protect outselves from the real hazards brought in by the use of chemical insecticides, time has come to favour primarity the use of biological control methods. Following this decision, special laboratory services and industrial installations should be organized for obtaining predators, parasites and entomopathogens before pest insect populations reach an epidemic level. Biological methods for the control of forest insect pests require no more, as far as installations and marketing are concerned, than that already generously provided for chemical control.

PRINCIPLES OF PRESERVATION AND REPRODUCTION OF VALUABLE GENE POOL OF CONIFEROUS POPULATIONS

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FDC: 165.3: 174.7

Decline and degradation of forest ecosystems are problems of great importance all over the world. As a result of over exploitation, industrial pollution, "plus selection" and other anthropogenous factors both the reduction of gene pool and the loss of adaptation mechanisms take place. That is why revealing and preservation of the rest of valuable gene pool and development of the principles of its reproduction should become the foundation of breeding programmes.

The formation of genetic structures of natural populations is conditioned by the direction of microevolutional processes, the rate and correlation of moving forces of evolution. Complex study of these processes by molecular-genetic markers (isoenzymes and monoterpen composition), karyological characteristics and morphological traits is conducted on such model species as *Pinus sylvestris* L. and *Larix sukaczewii* Dyl. Natural populations of different divergency level, panmixia or isolation level, contrast ecological conditions are used as the objects of study.

Vast areal of investigated populations of *Pinus sylvestris* from Prebaltic region and Saxony up to Urals and Siberia is characterized by high genetic polymorphism. Populations of *Larix sukaczewii* are characterized by lower genetic polymorphism. It might be the cause of catastrophic reduction of its area.

It is established that intrapopulational polymorphism in *Pinus sylvestris* and *Larix sukaczewii* in extreme conditions is higher than in many panmictic populations even in isolation. Consequently adaptation mechanisms of natural populations are expressed in their ability of preserving such genetic polymorphism level which is necessary for survival. Therefore the main principle of preservation and reproduction of valuable gene pool is to determine genetic variability level and to preserve it in artificial stands by no means.

RESPONSE OF FOREST TREES IN EASTERN NORTH AMERICA TO AIR POLLUTION STRESS: PHYSIOLOGICAL PROCESSES AT THE WHOLE-PLANT LEVEL

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FDC: 425.1: 425.3: 181.45: (7--11)

The chemical and physical properties of the atmosphere are changing as a consequence of anthropogenic activities, and the most notable from the perspective of forest growth are wet and dry deposited pollutants (i.e., O_3, oxides of S and N, H^+ ions), increasing levels of carbon dioxide, and UV-B radiation. Whereas the distribution of many of these stresses has implications for individual forest sites, all exhibit to some degree a hemispherical and/or global distribution such that concern for forest productivity is not restricted to specific regions. This review focuses on wet and dry deposition of atmospheric pollutants in eastern North America with a specific interest in (i) high elevation forests (Picea rubens L., red spruce) of the Appalachian Mountains and (ii) low elevation conifer forests (Pinus taeda L., loblolly pine) of the southeastern United States.

The response of forest trees to air pollution stress is mediated by both direct effects on physiological functions and indirect effects due to subtle changes in a tree's physiology that subsequently influence the individual's ability to compete for limited resources. Direct effects are a consequence of biochemical toxicity at physiologically sensitive sites in either the shoot (e.g., O_3 toxicity in the leaf) or root (e.g., Al toxicity in fine roots). Indirect effects include changes in winter hardiness, drought stress resistance, interspecific and intraspecific competitive ability at the stand level, and interactions with biotic pathogens. It is hypothesized that indirect effects are far more important in forest ecosystems than direct effects in understanding the long term consequences of air pollution stress.

Whereas direct effects of wet and dry deposited pollutants are highly specific at the biochemical level, a scientifically sound approach at the whole-plant level is to integrate these individual changes using carbon dynamics as a central commodity. This approach also links mechanisms of stress effects at the biochemical level (e.g., photochemistry of CO_2 assimilation) to responses in dry matter accumulation and partitioning at the whole-plant level. In both high and low elevation forests of eastern North America in which air pollution effects appear to be important ecologically, changes in carbon dynamics are emerging as a common response with the principal sites of action being net CO_2 assimilation, foliar retention of photosynthate, maintenance respiration, and photosynthate allocation to root systems.

The effect of air pollution stress on nutrition can have both positive and negative consequences. A generalized conceptual model of nutrient-mediated changes postulates three mechanisms of action: (i) increased foliar leaching of essential nutrients (e.g., Mg); (ii) absorption of otherwise limiting nutrients (e.g., N); and (iii) changes in soil acidity resulting in either increasing availability of toxic species (e.g., Al) or decreasing availability of essential nutrients (e.g., Ca). Whereas controlled studies have demonstrated both foliar leaching and absorption of essential nutrients as a function of wet and dry deposition of pollutants, the physiological consequences for forest trees are highly site and/or species dependent and principally reflect soil properties. Considerable uncertainty exists as to the levels and exposure dynamics required to induce toxic Al effects on the growth of tree roots or to alter the uptake of cations through competitive ion effects in the rhizosphere.

AMBIENT POLLUTION, PHYSIOLOGY AND GROWTH OF TREES AT THREE SITES IN BRITAIN

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FDC: 425.1: 425.3: 181.45: 181.3: (410)

Since March 1988, Sitka spruce (*Picea sitchensis*), Norway spruce (*Picea abies*), beech (*Fagus sylvatica*) and Scots pine (*Pinus sylvestris*), have been grown in open-top chambers at three sites in Great Britain. The sites have contrasting pollution inputs and climatic conditions and the trees at each site were planted into the ground with minimum disturbance of local soil.

The most northerly site, Glendevon is in Perthshire, Scotland. The second is in Derbyshire, northern England in an area of the country characterised by the largest concentrations of SO_2 and NO_2. The most southerly site, Headley is in Hampshire, where the predominant pollutant is O_3, occurring episodically during the summer months.

Measurements of photosynthesis and transpiration made throughout a growing season have shown that the ambient mixture of pollution present at Headley may significantly alter carbon uptake and water loss of both beech (*Fagus sylvatica*) and spruce (*Picea sitchensis*). Detailed analysis of the characteristics of photosynthesis revealed that both stomatal and mesophyll function were altered by pollution. Different responses were observed at the beginning of the growing season when first-flush leaves were present on the trees, and towards the end of the growing season, when second flush leaves were also present. First-flush leaves had lower stomatal conductances when grown in polluted air, compared with those observed in filtered air. In contrast, second flush leaves had higher stomatal conductance and a greater Jmax when grown in polluted air, possibly reflecting increased regeneration of RuBP, the substrate for photosynthetic CO_2 fixation.

Root growth of beech and spruce was also significantly altered after a season of exposure to ambient pollution at Headley. Root extension was significantly increased when trees were exposed to ambient pollution, compared with growth in filtered air, although small reductions of root dry weight increment were often associated with increased root lengths. Calculation of specific root length (SRL) suggested that roots produced in the polluted treatment were both longer and thinner than those produced in filtered air.

Needle and shoot growth were assessed for all species at all three sites during 1989. The results show that the interaction between climate and pollution may produce contrasting responses. For example, needle length was significantly enhanced for Norway spruce grown in ambient pollution (primarily SO_2 and NO_2) in Derbyshire; significantly reduced by pollution at Headley; whilst at Glendevon air quality had no effect on needle length. Recent data for destructive harvests of the trees at each site will also be presented in this paper.

CONTRÔLE BACTÉRIOLOGIQUE DE LA TORDEUSE DES BOURGEONS DE L'EPINETTE: PERSPECTIVES

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FDC: 453: 416.11: 174.7: 411.16: 145.7 Choristoneura fumiferana Clem.

La bactérie entomopathogène Bacillus thuringiensis sérotype H3a3b (Kurstaki), communément appelée Bt, est, depuis 1986, le seul insecticide recommandé au Québec et en Ontario pour contrôler la tordeuse des bourgeons de l'épinette (Choristoneura fumiferana C.) (Lepidoptera: Tortricidae), le plus terrible défoliateur des forêts de conifères de l'Est de l'Amérique du Nord. Bt est appliqué en suspensions concentrées permettant d'épandre la dose requise (20 à 30 x 10^9 Unités internationales/ha) dans un volume final de 2.5 à 3,0 L/ha; ces dispersions étant réalisées à l'aide d'avions de diverses capacités. De façon générale, lorsque les normes d'arrosage sont respectées et lorsque les populations de C. fumiferana ne dépassent pas 40 larves/45 cm, l'application de Bt permet d'obtenir des résultats satisfaisants au point de vue répression de cette tordeuse et protection du feuillage.

Il est donc essentiel de maintenir et même d'accroître l'efficacité et la rentabilité de cet insecticide microbien. Dans cette optique, nos travaux récents ont permis de développer deux suspensions ultra-concentrées de Bt permettant d'épandre la dose requise dans un volume final de 1,5 ou 2,0 L/ha. De plus, ces suspensions sont prêtes pour leur application aérienne. Il n'est donc pas nécessaire de les diluer sur les aéroports, ce qui réduit la durée des épandages. Ces préparations de Bt ont fait l'objet de dispersions aériennes expérimentales, afin d'évaluer leur potentiel pour la répression courante de C. fumiferana. Il a été ainsi constaté ces suspensions permettent de réduire de plus de 90% les populations de l'insecte et de protéger plus de 70% du feuillage des conifères.

Enfin, des expériences ont démontré qu'il est possible de produire du Bt à partir de substracts disponibles et très économiques, ce qui peut accroître la rentabilité et donc les perspectives de l'utilisation de cet insecticide bactérien.

IN VITRO PROPAGATION OF SOME TREE SPECIES SUITABLE FOR SEMI ARID REGIONS OF INDIA

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FDC: 165.442: 165.62: (213)

Seedling explants of *Albizzia lebbeck*, *A.procera*, *Prosopis juliflora* and *Pithecellobium dulce* were successfully employed for micropropagation of the species by culturing them in MS medium supplemented with suitable combinations of NAA and BAP. A higher concentration of BAP in the medium induced embryogenesis from the explant. The tissue culture technique was found to be useful both for mass propagation and induction of variability. The detailed study of regenerants in *Albizzia lebbeck* revealed the possibility of induction of variability in tree species using the in vitro technique with the purpose of selecting and further multiplying suitable clones with desirable characters depending on the requirements.

PHOTOACOUSTIC SPECTROSCOPY STUDY OF SO_2, OZONE AND ACID RAIN EFFECT ON PHOTOSYNTHESIS OF SUGAR MAPLE AND CORN

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FDC: 425.1: 425.3: 181.45: 161.32: 176.1 Acer saccharum Marsh.: 175.2 Zea Mays L.

Photoacoustic spectroscopy (PAS), a relatively recent technique allows to measure the photochemical energy storage (PES) and relative quantum yield of O_2 evolution (A_{OX}/A_{PT}) during photosynthesis by monitoring heat (A_{PT}) and O_2 (A_{OX}) emissions of an intact leaf. Because of certain unique features such as non-destructiveness, rapidity and modulation measurements, it is of considerable interest to study its applicability in forest decline research and in diagnosing the atmospheric pollutant injury to the plant in the field. As a primary step we are collecting data on sugar maple and corn plants treated either with SO_2 or ozone or simulated acid rain independently or in combination in the laboratory. We summarize our observations on isolated chloroplasts and intact leaves.

Studies with isolated intact mesophyll chloroplasts of corn revealed that chloroplast photosynthetic activity was insensitive to high concentration of SO_2 (5 $\mu L.L^{-1}$) for 10 min exposure under light. However at 10 $\mu L.L^{-1}$ SO_2, PES was inhibited indicating the possible diffusion of SO_2 as sulfite, since 10 $\mu L.L^{-1}$ SO_2 after hydration can result in relatively a high level of sulfite. Interestingly, sulfite incubation of isolated chloroplasts either in light or in darkness caused a decrease in PES. The decrease was more pronounced in light, indicating a light dependent inhibitory site(s) on photosynthetic electron transport chain. Addition of diphenylcarbazide caused a partial recovery in PES suggesting a site of damage at the water oxidizing system.

Short term (4 h) SO_2 fumigation experiments with sugar maple plants showed a concentration dependent differential effect of SO_2 on the photochemical activity of intact leaf. Both A_{OX}/A_{PT} and PES measured with 680-nm modulated light were increased in 0.05 $\mu L.L^{-1}$ SO_2 and decreased in 0.5 to 2 $\mu L.L^{-1}$ SO_2 fumigated plants. Photosynthetic action spectrum for PES decreased over control throughout the spectral range between 400 nm and 720 nm. The promotory effect of SO_2 can be explained considering sulfite at low concentration as possible electron acceptor. From our studies we conclude that SO_2 effect in leaves may be due to accumulation of sulfur ions and the reactive radicals.

Experiments with ozone fumigation of sugar maple plants showed an inhibition in O_2 evolution and PES at 0.05 $\mu L.L^{-1}$ for 4 h in light. Further studies are in progress to identify the critical dose of ozone, that inhibits photosynthesis, as detectable by PAS.

In another set of experiments, foliar application of simulated acid rain on sugar maple and corn caused a decline in O_2 evolution and PES. The decline was found to be pH dependent. Work is in progress to identify the subliminal doses of SO_2, ozone and pH and to understand their synergetic effect at the subliminal doses.

It is worth noting that the photoacoustic methodology enables us to detect damage to photosynthesis where there is no visible foliar injury, which holds good promise for use of this technique in early diagnosis of forest decline.

BIONOMICS OF *EUCOSMA HYPSIDRYAS* MEYRICK (LEPIDOPTERA: EUCOSMIDAE), A SERIOUS PEST OF SPRUCE IN WESTERN HIMALAYA, INDIA

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FDC: 453: 416.1 174.7 *Picea* ssp.: 145.7 *Eucosma hypsidryas* Meyrick: (540)

Spruce budworm, *Eucosma hypsidryas* Meyrick was observed to be a pest of economic importance infesting *Picea smithiana* in Western Himalaya, India. The infestation of the pest was as high as 30-35 per cent in Chhajpur, Jubbal and Kufri areas of Shimla District in Himachal Pradesh (above 2400 m.a.s.l.) during June, 1989. Study of the behaviour of the pest revealed that the females laid eggs on the young buds and only one larva inhabited each bud. It fed on the undeveloped needles inside without harming the outer-most nor the lower-most layers. These were spun together with silk and their tips remained enclosed in the bud cap, so that a hollow spindle-shaped chamber was formed, until eventually the whole of the shoot within was destroyed. The small (15 mm) whitish larva with black heads pupated in this chamber towards the beginning of the second week of June. Moths emerged about ten days after pupation, giving rise to the next brood, which perhaps entered into hibernation. Damage was mostly done during April-May. The attacked spruces could be identified by brown aborted tips at the branches. Trees of all ages were attacked. The destruction of the buds, as a result of feeding by the pest, prevented the normal annual formation of new shoots. Thus the vitality of the affected trees was weakened to such a degree that bark beetles and other borers were able to attack such trees. Thus spruce budworm is presumed to be a major cause of dying off of spruces in the Western Himalayan region. Detailed studies of the life cycle of the pest are in progress for a bioenvironmental control strategy.

THE GROWTH OF SOME INTERSPECIFIC HYBRID PINE SEEDLINGS AND THEIR CUTTINGS

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FDC: 232.13: 174.7 *Pinus* spp.

After performing controlled intra- and interspecific hybridization, seddlings were produced and used as donors for rooting of cuttings. From plants produced as seedlings (in 1979, 1980 and 1983) and as rooted cuttings (in 1981), the field experiment was set up in 1985.

European black pine (*Pinus nigra* Arn.) and hybrid pine (*P. x nigrosylvis* Vid.) cuttings root significantly better than Scots pine (*P. sylvestris* L.). The ortet age plays a definite role in the rooting ability. Dormant (winter) cuttings root better than the softwood (summer) cuttings.

In the field experiment, the hybrid plants and their back crossed progenies have better growth than European black pine plants. Their heights are same as heights of Scots pine plants, or slightly smaller. Such result was obtained with the group of plants of different ages, as well as with plants produced from rooted cuttings. Plagiotropic effect among plants produced as rooted cuttings was not noticed.

RELATIONSHIP BETWEEN PHOTOSYNTHESIS AND CHLOROPHYLL CONTENT OF DAHURIAN LARCH IN CONIFER-BROADLEAVED MIXED FOREST AND PURE FOREST

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FDC: 161.32: 174.7 Larix gmelinii Kuzeneva: 228.3: 228.2

The daily variations in photosynthesis, respiration and chlorophyll content of needles in different areas of the crown of Manchurian Ash-Dahurian Larch mixed forest and pure forest in Maorshan mountain forest farm, Northeast Forestry University in the notheast of China were measured using a Beckman CO_2 infrared analyzer.

The results indicate that photosynthesis rates and chlorophyll content of Dahurian Larch in mixed forest are higher than those of pure forest. Average photosynthesic rates of the crown in the eastern, southern, western and northern parts of any one tree are 0.2913, 0.2640, 0.2559 and 0.2240mg m-2 s-1 respectively, which are comparatively higher than those in mixed forest - east 0.1244, south 0.2069, west 0.1259 and north 0.1691mg m-2 s-1.

Daily fluctuations in photosynthesis in different areas of the crown present bipeak curves and significant "noontime snooze" phenomena which are related to water deficits. Contents of chlorophyll a, b and total in mixed forest are higher than those in pure forest. High diameter growth and photosynthesis and chlorophyll content present a direct proportional correlation in mixed forest, while in pure forest the correlation is not so obvious.

STUDY OF PHOTOSYNTHETIC CHARACTERISTICS OF DAHURIAN LARCH

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FDC: 161.32: 174.7 Larix gmelinii Kuzeneva

Photosynthetic and respiratory rates in different areas and layers of the crown in man-made 15-year-old Dahurian larch forest in Erlongshan Mountain forest farm, northeastern China, were measured locally for two years using a Beckman CO_2 Infrared Analyzer. Environmental factors were also measured.

The results indicate that photosynthetic and respiratory rates vary in different areas of the same tree. Photosynthetic rates in the eastern, southern, western and northern parts of the crown are 0.54, 0.46, 0.40 and 0.44mg m-2 s-1 respectively.

Photosynthetic rates in different canopy layers change with the seasons. The rates of photosynthesis and respiration of various layers change little in May. From June to August the photosynthetic rate is greatest in the lowest canopy layer followed by the upper layer, then the middle layer. In September the upper layer is greatest, then the middle, then the lowest.

Daily variation in photosynthesis and respiration presents a two-peak curve. Total chlorophyll content is different in various seasons, and the general order from highest to lowest is south, north, east and west sucessively.

ISOZYME ANALYSIS OF SOME TROPICAL RAIN FOREST TREE SPECIES

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FDC: 165.53: (213)

The many challenges facing the tropical rain forests include the understanding of the breeding systems and extent of genetic variation of its forest tree species for selection, breeding and conservation.

Isozyme studies of commercially valuable dipterocarp and non-dipterocarp hardwood species from the tropical rain forests of Peninsular Malaysia were initiated with the above aim in 1975 but, with little progress. Progress was hampered due to various factors related to availability of plant material especially seeds and difficulties to produce good enzyme activity in gels due to interference from compounds such as polyphenols or mucopolysaccharides present in these plant tissues.

Appropriate enzyme extraction techniques and buffer solutions with various antioxidants, reducing agents, and phenol binding or inhibiting substances for good enzyme activity have been developed to assay leaves, seeds and other plant parts when they are available. One such study using embryoes of germinants is reported here.

Single tree progeny arrays of three dipterocarp tree species viz. *Anisoptera laevis*, *Dryobalanops aromatica* and *Hopea odorata* and one non-dipterocarp tree species, *Samanea saman* at 9 - 14 isozyme gene loci showed variable genetic diversities for the different species. Heterozygosity was highest in *D. aromatica*; the other three species having almost a similar level of heterozygosity. The percentage of polymorphic loci ranged from 21% to 89% for the four species; highest for *D. aromatica* and lowest for *S. saman*.

Malic enzyme variation at one locus, *Me-2* for *D. aromatica* showed occurrence of rare heterozygotes in some families indicating possible spontaneous hybridisation with *D. ablongifolia* which occurs nearby. Polymorphism was observed for peroxidase (*Per-1* and *Per-2*), phosphogluconic dehydrogenase (*Pgd-1* and *Pgd-2*) and shikimate dehydrogenase (*Sdh-1*) for multiple embroyes from single seeds of *H. odorata*, indicating sexual reproduction as apposed to apomixis which was inferred earlier from studies on reproductive biology.

INTEGRATED PEST MANAGEMENT (IPM) IN FORESTRY

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FDC: 453: 411/414: 62

Our forests are limited resources, valuable for their multiple uses in terms of economical and environmental purposes with no substitute for them. Thus control of various forest pests deserves great attention. The article attempt to highlight the major problems of pest management in the forest ecosystem that are different from those in the agroecosystems. The problems differ because of the contiguous forested areas; life cycle of the forest and the usage of the forest resources.

Many of forest insect problems have been increasing in magnitude, because of inexpert exploitation of the forest and abuses of them. IPM is a systematic decisionmaking process and the resultant management actions which derive from considerations of pest-host relationships and evaluation of alternatives for managing pest populations at levels consistent with forest resources management objectives. In other words IMP consists of two basic elements: The decisionmaking process and the action program. The former begins with the detection of the pest and evaluation of its impact on the forest resource. Early detection permits different action programs than are used when a pest population reaches outbreak proportions. The decisioumaking process also identifies the resource management objectives and evaluates the cost of Pest control schemes and their impacts on the various resources associated with the site.

The pest control schemes must be compatible with the overall management and economics of the resource being managed. The action program consists of a mixture of prevention and direct suppression activities. Prevention includes those activities that make the forest less conductive to pest outbreaks. Direct suppression may involve one or more control tactics directed at the pest itself. It is important to understand that if a pest is treated directy without considering the cause of the outbreak, the pest may reappear once the treatment is finished. The article presents alternatives used to control a forest pest in an IMP program.

Chemical pestiacides are a part of IPM. In a fully implemented IMP program, however chemical use patterns may change because of early detection which could reduce the amounts of pesticides used. Forest pest management has emerged based on two areas of populations dynamics and forest ecology. The study of causes of population fluctuations can provide clues to suppression tactics.

IN VITRO SHOOT FORMATION FROM THE PRIMARY NEEDLES OF *PINUS TAEDA* L., *P. RIGIDA* MILL., AND *P. TAEDA* X *RIGIDA*

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FDC: 165.442: 174.7 *Pinus taeda* L.: 174.7 *Pinus rigida* Mill.

Micro-propagation is favored in terms of mass-propagation of the fixed genotype in a given time. However, organogenic responses are often confined to juvenile explants. The *in vitro* techniques have been probed in many forest tree species to overcome maturity.

Primary needles of 2-3 week old shoots *in vitro* produced from the axillary buds were placed on solid media or in liquid ones modified from Gresshoff and Doy (1972) and from Schenk and Hildebrandt (1972). Possible combinations of naphthaleneacetic acid (0.01 or 0.1 mg/l) and benzylamino purine (0.1, 0.5, 1, 2, or 5 mg/l) were made for explant stimulation. After 3-4 weeks initiation, explants were transferred to non-hormonal solid media every 3-4 weeks.Illumination was about 1506±540 lux at the level of the tissues in the growth room under 25±2°C. A 16-hour photoperiod per 24 hours was used. Half-strength medium was prepared for all the subcultures.

In all the explants initiated on solid medium, no organogenesis was observed. However, a very low number of explants stimulated in liquid media were observed developing buds at their basal ends without forming callus. Explants forming callus did not appear to be capable of organogenesis. No organogenesis occurred in the concentration of 0.1 mg/l NAA; 0.1 and 0.3 mg/l BAP. Most shoots were formed at 2 and 5 mg/l BAP. The following table shows the number of primary needles producing adventitious shoot(s) after 3 subcultures.

Medium	NAA (mg/l)	BAP (mg/l)	*Pinus taeda*	*Pinus rigida*	*Pinus taeda* x *rigida*
Ref. 1.	0.01	1	0/30;0/30	0/27;0/30	1/30;0/30
		2	1/30;1/30	0/25;1/27	1/30;0/30
		5	2/25;1/25*	1/30;1/30	3/30;1/30
Ref. 2.	0.01	1	0/27;0/30	1/30;1/35	1/30;0/30
		2	0/30;1/25	1/30;1/35	0/28;1/30
		5	2/29;1/30	2/32;1/30	2/35;1/25

* 2/25;1/25 represents that 2 explants produced adventitious shoot(s) among 25 explants tested in one replication, and 1 did among 25 in another replication.

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HYPHAL HYPERPARASITIC RELATIONSHIPS BETWEEN ECTOMYCORRHIZAL FUNGI AND *Rhizoctonia solani*

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FDC: 443: 411.16: 176.1: 172.8 *Rhizoctonia solani*

Eighteen ectomycorrhizal fungi were used to study hyphal hyperparasitism of *Rhizoctonia solani* in Potato-Dextrose-Agar dishes. Under the light microscope, 8 of 18 ectotrophic fungi were found to have hyphal hyperparasitism which could be commonly grouped into 4 types: appressed growth, coiling, penatration and lysis. In maiden applications of scanning electron microscopy and x-ray microanalysis to the study of hyperparasitic relations between *Rhizoctonia solani* and the 3 of 8 mycorrhizal fungi, the substance transferences of several elements including P, S, K and Ca from *Rhizoctonia solani* to mycorrhizal fungi were discovered in all the interactions except lysis.

Poster Abstracts
Résumés d'affiches
Kurzreferate füt Postersitzungen
Descripción resumida de posters

Poster abstracts have been arranged in alphabetical order of authors' names.
Les résumés d'affiches ont été disposés par ordre alphabétique des noms d'auteurs.
Die Kurzreferate für Postersitzungen sind in alphabetischer Reihenfolge der Autoren aufgeführt.
Descripción resumida de posters dispuestos por orden alfabético de los nombres de los autores.

201 Results in the Clonation of *Melia azedarach* and *M. toosendam* Resistant to the Cold

Abedini, W.I.; Ciocchini, G.; and Marlats, R.M.
Faculty of Agronomy. National University of La Plata. Argentine Republic

The variability observed in the results of the descendants of the selected specimens by resistance to the cold of *Melia azedarach* and *M. toosedam* may surpass through the vegetative propagations of the selected specimens.

In the Experimental Farmland of the Faculty of Agronomy of the National University of La Plata situated to the 34° 55'; 57° 57' LW 15 m.s.n.m. Province of Buenos Aires - Argentine Republic, selections of *Melia azedarach* and *Melia toosedam* cultures selections were made which survived to low temperatures.

It's important to mention that the herbaceous material of branches in lettargy was homogeneizd in 40 cm long and with different diameters, which determined the degree of asociation between the fresh weight of the stem cutting and the fresh weight of the roots, leaves and shoots, getting a high positive correlation among these, and a great degree of dependence was also obtained between the fresh weight of roots and the fresh weight of leaves and shoots.

The used method for the vegetative propagation consisted on the inmersion of the stem cuttings base in a solution of 40 p.p.m. of Indole Acetic Acid for 24 hours. Previously washed with running water for 48 hours. After 90 days in inert substrate under green hoose conditions with controled temperature and light, the following results were obtained in percentage of complete plants:

Melia azedarach cv. *azedarach* 25%; *M. azedarach* cv. *Garrasino* 61%; *M. azedarach* cv. *Gotz* 7% y *M. toosendam* 46%.

It concludes in the differential answer of the taxons for this taking roots method and the influence of quality in the quantity of produced plants.

202 Aspects of Biology, Behaviour and Control of the Saxaul Locus in Iran

E. Adeli
University of Tehran Faculty of Forestry, Karaj, Iran.

This poster outlines the present state of knowledge of the Saxaul locust (*Dericorys albidula* Serv.) and draws the biology, behaviour and present control in Iran.

About 500,000ha of sand dunes in Iran have been gradually planted with various species of Saxaul trees (*Haloxylon* spp.), since 20 years ago.

At the present time many insects injure this plant; for example *Dericorys albidula* Serv. is one of the serious pests of *Haloxylon*. The Saxaul locust passes the winter in the egg stage in sandy soil. The overwintered eggs hatch early in Spring, the nymphs feed on twigs. After moulting 5 times, the adult appears in mid-June. About 5 months feeding by Saxaul does great damage.

According to our research on its control, Fenitrothion has been tested adequately against *Dericorys albidula* Serv., and good control has been achieved consistently with technical grade Fenitrothion 96 percent strength applied at ca. 400g ai/ha.

203

WINTER TEMPERATURE FLUCTUATIONS AS A MECHANISM CAUSING POLE BLIGHT ON WESTERN WHITE PINE.

Auclair, A.N.D., Forestry Canada, Laurentian Forestry Centre, Sainte-Foy, Quebec, Canada.

The onset of crown dieback and other "poleblight" symptoms on western white pine (*Pinus monticola* Dougl.) in the Pacific Northwest United States and British Columbia (1936-1958) coincided with marked thaw-freeze and frost events in the fall and winter of 1935-36. In contrast to results of Leaphart and Stage (Ecology, 1971), an event analysis of meteorological records indicated clearly that the injury mechanism resulting in persistent dieback was not drought but freezing injuries to the xylem (viz. cavitation); hypersensitivity to heat and water stress in 1936 and in subsequent years was likely. Similar winter temperature extremes were present at the onset of forest dieback in Northern Hardwoods (eastern North America) and in Norway spruce (Central Europe) suggesting the climate-cavitation-forest dieback mechanism may be universal.

204

CLONAL MICROPROPAGATION OF FOREST WOODY PLANTS IN VITRO

Baiburina, R.K., Ermakov, V.I. (Botanical Garden, Bashkir Sci. Centre, Ural Division Acad. Sci. USSR, Ufa, USSR)

Karelian birch is characterized by peculiar wood structure, its decorativity is highly valued in the world market.

As a result of intensive cutting its resourses are fully exhausted. Recently valuable hybrids of Karelian birch couldn't be widely used in timber industry for their incapability to vegetative propagation. The elaboration of biotechnology methods affords a great opportunity to their usage in intensive forestry. In our laboratory there were developed the technologies of clonal micropropagation in vitro of valuable Karelian birch hybrids and perspective forms of black poplar with decorative wood (not propagated by ordinary cutting) from mountain populations in Krasnodar region. For one year introduction in culture, propagation of shoots, rooting and transfer to soil are possible. The mentioned technologies make industrial usage of hybrids and forms of Karelian birch and poplar possible in forestry, in particular for creation of timber-resource base for production of decorative wood.

205 Early prognosis of the Lepidopterian forest pest's outbreaks transgeneration pathogen transmission

A.Y. Baranov
Institute of Genetics and Selection
of Industrial Microorganisms
Moscow, USSR

The presence and spreading of insect pathogens, first of all viruses and microsporidia, affect on the insect outbreaks, and, finally, on the program of forest protection. Deeply infected insects, especially in the stage of egg, can not emerge, or die at the 1 - 3 larval instar. On some moth (*L.dispar*, *H.cunea*, *E.chrysorrhoea*, *O.antiqua* **) the method of early diagnosis of pathogen distribution was shown. It consists of detecting the chorion degeneration, such as abnormal structure of micropylar rosette, closed micropyle, closed aeropyle, destruction of ridge system, destruction of the sculpture of polygons, etc, all caused by transovarial transmission of entomopathogens.**

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206 SOLAR CONVERSION EFFICIENCY OF NORWAY SPRUCE SEEDLINGS (Picea abies /L./Karsten) AT THREE SITES IN SLOVENIA,YU

Batič,F.,Lovrec,M. (Institute for forest and wood economy,Ljubljana,Večna pot 2)

In the framework of IUFRO cooperative project on Solar Radiation Interception and Conversion Efficiency in Whole Plants three sets of research plots were established with four years old seedlings of norway spruce in 1987; latitude 46° N,longitude 15° E, mean annual rainfall 1270-1600 mm, mean annual temperature 5,9 and 8,9°C , mean annual solar radiation about 4,5 GJ/m^2. Two sets of plots, 5 plots with 50 seedlings planted on each, were established on forest sites on altitude of about 800 m. This pair of plots has similar growth conditions concerning climate and soil but differs on the level of air pollution. The third plot is located near forest institute (altitude 300 m) on the clearing with similar soil type. Following instructions of IUFRO project the distribution of seedlings' biomas accounted: stem 29%, branches 15%, needles 29%, roots with stump 26,5%, stump 5,5%. Solar conversion efficiency of spruce seedlings was determined about 0,43 kg/GJ. All data cited are results of sampling in the vegetation period spring - autumn 1988.
Besides measurements of biomass distribution and solar conversion efficiency determination the measurements of photosynthetic and transpiration capacity , determination of water potential and chlorophyll content as also micorrhization of fine roots were carried out on sampled seedlings.
The experiment will be completed in the autumn of vegetation season 1990.

207 SOMATIC EMBRYOGENESIS IN *PICEA ABIES* AND *PINUS PINASTER*

BERCETCHE J. and BELGACEM N.
AFOCEL-Station de Biotechnologies-Domaine de l'Etançon-77370 Nangis-FRANCE

Somatic embryogenesis was reported for *Picea abies* and *Pinus pinaster* (VON ARNOLD and HAKMAN, 1986) using immature embryos and cotyledons of young plantlets and for *Pinus pinaster* using immature embryos (HUGUES-JARLET E. and BERCETCHE J., submitted). The efficiency of development of plantlets from somatic callus is very low, especially for pines. This paper compares the embryogenesis events in *Picea abies* and *Pinus pinaster*. A system for high frequency development of plantlets in *Picea abies* is presented. Maturation frequency as high as 80 % has been obtained. Fifty to sixty percent of the somatic embryo plantlets developed roots. These plantlets were hardened and compared with seedlings.

In *Pinus pinaster*, the first stages of embryo development (globular stage) can be achieved by the subcultivation on a new medium every third day. Few embryoids continued to grow and showed development of cotyledons. Efforts are underway to induce these embryos to germinate and form whole plants.

208 SOIL-PLANT INTERACTION AND THE DYNAMICS OF WATER STRESS.

Pierre Y. Bernier, Forestry Canada, Quebec Region, Laurentian Forestry Centre, Sainte-Foy, Québec, Canada.

When studying plant water stress in the field, measurements of soil effects on the plant water relations must be performed in order to isolate the effects of the plant's own physiology. In order to do this, soil water tension must be measured, not only in the bulk of the soil, but also at the soil-root interface. Indirect measurements of water tension at the soil-root interface were performed on two-year-old black spruce (*Picea mariana* Mill.) seedlings, placed in three soils with different textures and compositions. Bulk water tension in the three soils varied between 0.05 and 2 MPa at the time of measurement. Results show that the soil water tension at the soil-root interface depends on the bulk soil water tension, the hydraulic properties of the soil, and the evaporative demand transmitted to the plant's roots. For any given bulk soil water tension, soil water tension at the soil-root interface increased from fine to coarse soils. Differences of up to 1 MPa were computed between bulk soil water tension and that at the soil-root interface. If such measurements are not carried out, variations in the root resistance caused by this soil-plant dynamic can be falsely attributed to the plant itself.

209 BIOCHEMICAL PROGRESS IN UNDERSTANDING OF MATURATION OF SEQUOIA SPECIES

BON M.C., MONTEUUIS O. and FRANCLET A.
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Clonal propagules from mature trees are physiologically older than those from juvenile plants and often display such undersirable characteristics as plagiotropic growth and reduced or even none rooting capacity. However, recent demonstrative results state that rejuvenation can be successful for *Sequoiadendron giganteum* and *Sequoia sempervirens* through two *in vitro* techniques. It was particularly true considering meristem culture of mature giant sequoias, with the possibility for meristems removed during budbreak time to regenerate a truly rejuvenated cycloclonal line. On the other hand, rejuvenation of mature *Sequoia sempervirens* was established through production of plantlets originated from epiphyllous buds.

To obtain informations about physiological and genetic mechanisms underlying maturation and rejuvenation process, protein composition in apices of juvenile, mature and rejuvenated mature clones were compared. It appeared that a membrane protein of 16.000 daltons and called J 16 is related to juvenility of giant sequoia. In the same way, J 16 assays and associated western blot confirmed the rejuvenated status of a 100-year-old ortet. We proposed also to evaluate the significance of the genetic control of the topophysis phenomenon through protein pattern analysis in mature topoclones of *Sequoia sempervirens* before and after rejuvenation. Proteins were separated by 2-D micro or macro electrophoresis.

The importance of these data in relation to maturation of sequoia species will be discussed.

210 SAMPLING PROCEDURES FOR WITHIN-TREE POPULATIONS OF Tomicus piniperda (Coleoptera: Scolytidae)

Bouhot, L.(1), Debouzie, D.(2) and Lieutier, F.(3)

(1) DERF, Départ. Santé des Forêts, 1 ter av. de Lowendal, 75007, Paris
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(3) INRA, Zool. forest., Ardon, 45160 Olivet.

The distribution of attacks by Tomicus piniperda was studied on Scots pines with 3 experimental designs set in the Orleans forest (1986, 87, 88). 21 trap-trees and 14 standing pines were exhaustively sampled. Two types of sampling procedures are proposed. The intensive ones are based on a systematic sampling along the trunk with hypothesis of linearity for the number of attacks between 2 sampling units. The precision was calculated with a subsampling. The counting of attacks on a 25cm long cylinder every meter was recommended for it gives neglible bias, and precisions of about 10 to 25% (at 5% risk). In the extensive procedures, the choice of sampling heights was realized through a stepwise multiple regression between total number of attacks and attacks counted on each 25cm cylinder. The cylinders beginning at 1, 3.5 and 8 meters were selected. Linear (multiple) regressions were then calculated for these 3 cylinders (and cylinder combinations). Sampling these 3 cylinders, the average absolute bias is about 10%. The intensive procedures could be used for specific studies of population dynamics and the extensive ones for the survey of population levels in forests.

211 THE EFFECTS OF O_3 ON ACER SACCHARUM SEEDLINGS GROWN IN OPEN TOP CHAMBERS.

Boulais, C[1]., Mauffette Y.[1] and Renaud, J.P.[2] ([1] GREF, Univ. du Québec À Montréal, H3C 3P8. [2] CRA, MAPAQ, Ste-Foy).

Ozone (O_3) has been establish to be a contributing factor to maple decline. Diurnal photosynthetic activity of *Acer saccharum* seedlings (5 years) were measured during the 1989 season at the Centre de Recherche Acéricole field station located at Tingwick, Québec. These seedlings were grown in an open site (field), understory and in open top chambers (OTC). Seedlings grown in the OTC were exposed to three treatments: ambient air, filtered air and 3 X ozone concentration. The photosynthetic activity was established with the portable photosynthesis system (Li-6200). The peaks in the photosynthetic activity occurred in early mornings ranging between 1 to 8 µmol/m²/s. Photosynthesis rates were significantly lower for seedlings exposed to 3 X ozone concentration compared to seedlings present in abient and filtered air. A comparison with seedling growing in the field and in the understory showed that the photosynthetic activity observed in the field was similar to OTC; conversely, seedlings present in the understory had lower rates and reached maximum rates at mid-day. These results suggest that ozone will significantly decrease productivity and may be an important airborne pollutant contributing to forest decline. (funded by the MAPAQ).

212 DETECTION OF THE FOUR-EYED SPRUCE BARK BEETLE, A SECONDARY PEST OF SPRUCE BUDWORM-DAMAGED STANDS.

Bowers, W.W. (Forestry Canada, Newfoundland and Labrador Region, St. John's, Newfoundland).

Pheromone-based communication by the four-eyed spruce bark beetle, *Polygraphus rufipennis* (Kirby), was investigated in the field and the laboratory. Greenhouse cages baited with male-infested logs caught significantly more beetles than cages with female-infested logs, male and female-infested logs, uninfested logs or unbaited control cages. In the laboratory, an open arena airflow olfactometer was used to test the response of adults to various volatile stimuli. Both sexes responded to the odor of male-produced frass. Analysis of Porapak Q-captured volatiles disclosed that males produce 3-methyl-3-buten-1-ol. Identification of the aggregation pheromone could lead to the development of a valuable detection, monitoring or management tool for use in future pest management strategies.

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CONTROL OF THE BARK FEEDING WEEVIL (*HYLOBIUS ABIETIS*) USING A CONTROLLED RELEASE FORMULATION OF THE INSECTICIDE CARBOSULFAN

A. Castellano, Incitec International, P.O. Box 140, Morningside, Queensland 4170, Australia.

The pine weevil, *H. abietis*, is a major pest of coniferous reforestation throughout northern Europe. The weevil breeds primarily in recently clear-felled areas. Oviposition and larval development occur in the dying roots of freshly felled trees, and in lying logs and branches. The emerging weevils feed on young pine seedlings, gnawing the bark and causing large stem lesions that can lead to stunted growth and tree death. Young pines are most susceptible during the first two years after planting out. Results from replicated field trials initiated in France in 1987 showed that a single application at planting of a granular controlled release formulation (Marshal® suSCon®) containing the carbamate insecticide carbosulfan (100 g/kg) effectively protected plants from severe weevil attack over the critical two year establishment period. The level of damage control obtained was significantly greater than that provided by repeated foliar sprays of lindane and synthetic pyrethroids. Carbosulfan and its metabolites are non-persistent. The use of a controlled release formulation therefore results in no persistent chemical residues, and provides an environmentally acceptable alternative to organochlorine insecticides. The dry, dust-free granules also provide appreciable safety benefits to users by reducing both oral and dermal toxicity. ®Marshal and suSCon are registered trademarks of FMC and Incitec respectively.

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TRANSIENT EXPRESSION OF CAT, GUS, AND NPT II GENES IN HYBRID LARCH (*LARIX EUROLEPIS*) PROTOPLASTS

Pierre J. Charest and Krystyna Klimaszewska. Molecular Genetics and Tissue Culture group, Petawawa National Forestry Institute, Forestry Canada, Chalk River, Ontario, Canada, K0J 1J0.

Protoplasts isolated from an embryogenic cell line of hybrid larch (*Larix* x *eurolepis*) were electroporated with either a square wave pulse generator or a decay pulse generator with different gene constructions. Expressions of chloramphenicol acetyltransferase (CAT), neomycin phosphotransferase, and b-glucoronidase genes were detected in transient assays. The genes were hooked up to either the CAMV 35S promoter, the NOS promoter, or the WIN promoter of gene IIk of tomato. Expression was lowest with the NOS promoter. The highest levels of expression of the chimeric genes were obtained with the square wave pulse generator and the CAT appeared the most sensitive reporter gene. The b-glucoronidase gene expression was detected *in situ* by reaction with X-glu or by fluorescence by reaction with MUG; however, an endogenous background level of reaction was observed with non-electroporated protoplasts. These results showed the possibility of using genes designed for crop plants in conifer genetic engineering.

215 MITOCHONDRIAL GENOME ANALYSIS IN THE CONIFER, *LARIX*

L. DeVerno*, P.J. Charest*, and L. Bonen†. *Petawawa National Forestry Institute, Chalk River, Ontario K0J 1J0. †University of Ottawa, Department of Biology, 32 George Glinski, Ottawa, Ontario K1N 6N5.

The basic information available on conifer mitochondrial genome organization, complexity, and mode of inheritance is very limited, despite the ecological and commercial importance of conifers. We have isolated mitochondrial DNA from *Larix* species and are using restriction endonuclease and Southern hybridization analyses to examine the physical complexity of the genome and to study organelle inheritance patterns. The use of specific wheat mitochondrial gene probes in these heterologous hybridization experiments is also providing information about individual gene structure and organization in larch mitochondria. DNA libraries of total genomic and mitochondrially-enriched *Larix* DNA have been constructed in the EMBL3 vector and will be used for studies of gene structure and expression.

216 LONG-TERM DEPLETION OF CALCIUM AND OTHER NUTRIENTS IN EASTERN U.S. FORESTS

C.A. Federer, J.W. Hornbeck, L.M. Tritton, C.W. Martin, R.S. Pierce, and C.T. Smith. USDA Forest Service and University of New Hampshire.

Both harvest removal and leaching losses can deplete nutrient capital in forests, but their combined long-term effects have not been assessed previously. We estimated changes in total soil and biomass N, Ca, K, Mg, and P over 120 years from published data for a spruce-fir site in Maine, two northern hardwood sites in New Hampshire, central hardwood sites in Connecticut and Tennessee, and a loblolly pine site in Tennessee. For N, atmospheric inputs counterbalance the outputs, and there is little long-term change on most sites. For K, Mg, and P, the total pool may decrease by 2%-10% in 120 years depending on site and harvest intensity. For Ca, net leaching loss is 4-15 kg/ha/yr in mature forests, and whole-tree harvest removal could reduce total soil and biomass Ca by 20%-60% in only 120 years. We estimated unmeasured Ca inputs from rock breakdown, root-zone deepening, and dry deposition; these should not be expected to make up the Ca deficit. Acid precipitation may be the cause of current high leaching of Ca. Although Ca deficiency does not generally occur now in acid forest soils, it seems likely if anthropogenic leaching and intensive harvest removal continue.

217 PRELIMINARY STUDIES ON DIEBACK OF EUCALYPTUS CLOEZIANA SEEDLINGS IN THE NORTHERN GUINEA SAVANNA

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The incidence of *Paecilomyces varriotti* Bainier was found on *Eucalyptus cloeziana* in the forest nursery set up by Japan International Cooperative Agency (JICA) in collaboration with Forestry Research Institute of Nigeria. The nursery is situated in the Northern Guinea Savanna area of Nigeria. The thermophilic fungus which is without any record of pathogenic action in the country was found on *E. cloeziana* seedlings showing evidence of dieback. All isolations made proved constant association of the fungus with the disease. However use of benlate was found to reduce the incidence of the disease as well as adequate daily watering of the seedlings.

218 SEPARATION AND STUDY OF THE MALIC ENZYMES FROM OAK LEAF CELLS

D. Gérant and P. Dizengremel, Maître de Conférences and Professor, Laboratoire de Physiologie Végétale et Forestière, Université de Nancy I, BP 239, 54506 Vandoeuvre, France.

The isolation and purification of two different malic enzymes were successfully performed from oak leaves (*Quercus robur* L.). In herbaceous plants, this kind of enzyme, decarboxylating malate into pyruvate, is known to work both in cytosol (NADP - dependent form) and in mitochondria (NAD- dependent form). The important role of these enzymes would consist in the building of an equilibrium in the availability of malate and pyruvate for a further mitochondrial respiratory use. The presence of deleterious compounds (phenols, tanins) makes difficult the extraction of intact enzymes from tree tissues and the elaboration of a protective medium allowed to get a crude extract showing a correct malic enzyme actvity. After desalting, the use of a DEAE-Sephadex column led to the separation of two different malic enzyme fractions, 25 fold purified. The two enzymes can be distinguished by their specific cofactors. The NAD- dependent malic enzyme was activated by Mn^{2+} whereas the NADP- dependent malic enzyme required Mg^{2+}. These properties are similar to those known in herbaceous leaf cells. Although the isolation of mitochondria containing the NAD- malic enzyme from tree leaves is still unsuccessful, the comparison of the two enzyme activities could help to a better understanding of the cellular events during the course of leaf life.

219 GENETIC RESOURCES IN SWEET CHESTNUT (Castanea sativa MILL.) AND THE PROBLEMS RELATED TO THEIR CONSERVATION IN ITALIAN ORCHARDS

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Sweet Chestnut is a species which has been cultivated for a long time and asexually propagated. Since Roman times the origin of Chestnut stands is connected with man's activity. Grafted Chestnut stands are the results of a long artificial selection process. The genetic structure of the so-called "varieties", which have been developed through grafting, is still unknown. The specification of the cultivated varieties is very difficult, because they are usually described and classified only according to their genetic origin. This kind of agamic propagation may have caused a loss of genetic variability, which can be detected in grafted Chestnut orchards. This study deals with the question of whethof different individuals belonging to the same variety, are genetically identical or not. Individual trees collected in different areas have been analysed for 8 enzyme loci. The material represent several varieties cultivated in Northern, Central and Southern Italy. Data were analysed at different levels to test: a) the homogeneity of the individuals within each variety; b) the homogeneity of the varieties within each geographical region; c) the genetic distance among the varieties. Results show high homogeneity (a) among individuals and (b) among varieties of the same area; on the other hand, the comparison among the different regions (c) reveals high values of genetic distance. These data demonstrate how the genetic resources have been strongly manipulated by man's activities which caused a loss of genetic variation in Chestnut populations.

220 CLASSIFICATION OF HEMLOCK LOOPER DEFOLIATION FROM SATELLITE IMAGERY.

Franklin, S.E. (Department of Geography, The University of Calgary, Calgary, Alberta), and Hudak, J. (Forestry Canada, Newfoundland and Labrador Region, St. John's, Newfoundland).

Defoliation by the hemlock looper, Lambdina fiscellaria fiscellaria (Guen.), in balsam fir, Abies balsamea (L.) Mill., forests in Newfoundland was classified from satellite imagery. High resolution SPOT images were acquired before and after defoliation in 1987 and 1988. The image analysis included visual inspection of colour composites, unsupervised and supervised classifications, and application of general linear models. Results were compared to both field checks and sketch maps generated from helicopters by the Forest Insect and Disease Survey of Forestry Canada. The unsupervised classification showed one class of defoliation, but supervision of the classifier enabled separation of three levels labelled as light (less than 30%), moderate (30% to 60%), and severe (60% plus). The classification was at least 90% accurate as determined by a combination of random sampling, discriminant analysis and field verification. The digital map of defoliation classes was transferred to the provincial forest inventory ARC/INFO GIS to calculate area and volume statistics for individual stands.

221 ECTOMYCORRHIZAL INOCULATION: A TOOL TO IMPROVE THE QUALITY OF CONTAINERIZED SEEDLINGS IN NURSERY

J. Gagnon and C.-G. Langlois, Direction de la recherche et du développement, Ministère de l'Énergie et des Ressources, Québec, Canada.

This study was carried out to demonstrate the feasibility of large scale production of ectomycorrhizal seedlings in nursery. Jack pine, black spruce, white spruce, tamarack, and red oak seedlings were grown under diverse cultural conditions. They were inoculated at the time of sowing with different ectomycorrhizal fungi and inoculum types (solid and liquid inoculum) produced either experimentally or commercially. Appropriate fertilization schedule providing adequate N and P substrate fertility levels and tissue nutrient concentrations was necessary for a good mycorrhizal development of these species. Since commercial inoculum of quality can be produced in large quantity, it is now possible to realize large scale ectomycorrhizal inoculation of containerized seedlings in nursery.

222 CONTRIBUTION A UNE MEILLEURE CONNAISSANCE DU BOUTURAGE DU DOUGLAS

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La présente affiche fait état des progrès réalisés en France depuis près de 10 ans dans la méthode de bouturage du Douglas. Quatre domaines ont été plus précisément étudiés : la culture des pieds-mères, le traitement des boutures, les conditions d'environnement et l'élevage des boutures en pépinière. Les observations faites sur les pieds-mères et la qualité des boutures concluent à l'amélioration de l'enracinement par des techniques intensives de culture (substrat, fertilisation équilibrée, tailles réactivantes). Néanmoins, ces conditions ne sont rendues suffisantes que si le matériel végétal est prélevé au stade physiologique optimal : à partir du mois de Décembre pour l'hémisphère Nord. On a montré que le passage au froid des boutures pouvait augmenter de 20 % le pourcentage d'enracinement, et provoquer une restauration rapide de l'orthotropie. Les besoins des boutures en auxine exogène et en agents stimulateurs augmentent avec l'âge des pieds-mères. Sur le plan climatique, on a constaté qu'une chaleur de fond de 22° C pouvait améliorer fortement l'enracinement, mais qu'appliquée au-delà d'un mois elle pouvait être dépressive. Enfin, la croissance des boutures en pépinière est favorisée par l'emploi de substrats de culture aérés, à plus forte raison lorsque les systèmes racinaires sont bien développés. Ces améliorations restent toutefois très dépendantes de la position de la bouture sur le pied-mère. Les résultats évoqués dans cette affiche permettent ainsi d'ouvrir la voie à une foresterie clonale, susceptible de mieux valoriser les gains génétiques.

223 ROOT-PRUNING OF BLACK SPRUCE SEEDLINGS GROWN IN CONTAINERS

B.-M. Gingras and C.-G. Langlois, Direction de la recherche et du développement, Ministère de l'Énergie et des Ressources, Québec, Canada.

The purpose of this study was to minimize root malformations of containerized seedlings through root-pruning treatments. Five types of containers (IPL 45-110 + $CuCO_3$, Trimroot 112, Rootmaker, Jiffy #70 and #140, and wire-mesh) designed to optimize root morphology, were used with black spruce seedlings. Three nitrogen levels of fertilization were applied to each container-type treatment. Both chemical and aerial root-pruning treatments permitted to decrease significantly the incidence of root malformations. Pruned roots have a high capacity of growth recovery which should ensure a good horizontal distribution of lateral roots in the field. Root-pruning treatments may contribute to the production of well-balanced seedlings with a root system that will permit a better soil anchorage as well as a greater capacity to absorb soil water and nutrients. These advantages should improve survival and accelerate seedling recovery on planting sites.

224 CHANGEMENTS PHYSICO-CHIMIQUES DES PRÉCIPITATIONS DANS UNE SAPINIÈRE À ÉPINETTE ROUGE

Guy Gosselin, Service de la recherche appliquée, Ministère de l'Énergie et des Ressources, Québec, Canada

Différents collecteurs ont été installés dans une sapinière à épinette rouge afin d'étudier les modifications physico-chimiques des précipitations au contact de la cime des arbres et de certains horizons du sol (organique et Aej faiblement développé). Les résultats obtenus jusqu'à maintenant révèlent que le niveau d'acidité est légèrement supérieur au-dessus du couvert forestier comparativement à ce qu'on mesure sous couvert forestier. Les nitrates pour leur part sont en concentrations plus faibles sous la strate arborescente alors que les sulfates augmentent de façon significative par l'apport des dépôts secs. Les cations basiques sont nettement plus élevés sous la couverture végétale, témoignant ainsi d'un lessivage de ces derniers dû à la charge acide provenant de la pollution. Sous la matière organique, l'acidité augmente de façon très importante à cause des acides organiques libérés par la minéralisation. La majorité des éléments en solution augmentent également pour être par la suite modifiés au contact d'un horizon minéral Aej très peu développé.

225 EVIDENCE OF SOIL ACIDIFICATION DUE TO ACID PRECIPITATION AT A HIGH ELEVATION SITE IN SOUTHERN QUEBEC, CANADA.

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Due to the lack of long term studies, in southern Canada, it is very difficult to find evidence that acid precipitation has caused soil acidification. This study was undertaken to examine the effects of different acid loadings on soil chemistry along a toposequence. Because the mountain is in cloud about 40% of the time, acid precipitation loading on forest and soil is directly related to elevation. Soils on a transect across Roundtop Mountain, near Sutton, Quebec, show a pattern of chemistry that corresponds to the loading of acidic deposition. Soil solutions collected at two elevations show very different levels of both SO_4 and Cl, the two major anions in fog water. Surface horizons of soils located above 850 m have pH in water as low as 3.7; base saturation is extremely low (<5%) and aluminum saturation in mineral horizons exceeds 95% in many cases. Lower on the mountain slope (below 650 m), pH is slightly higher (about 4.1) and base saturation rises to approximately 20%. The results appear to support the hypothesis that soil acidification along the transect is a function of acid precipitation loading.

226 HOLOGRAPHIC BIOLOGY AND FOREST SCIENCE

Liu Jianwei and Wang Yitao

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Two decades ago, the bioholographic law was put forward by Prof. Zheng Yingquig of Shangdong University. It has formed a new branch of biology,-holographic biology. The more attention has been paid to it because it is widely used in medicine and agriculture. So it will also be useful to apply it to forestry. The bioholographic law and the embryo containing the information of the whole organism (ECIWO) are the core of holographic biology. The bioholographic law brings out the holographic corresponding relationship between one part and the other, one part and the whole body of the organism, the ECIWO is a relatively independent part in structure and function. These principles can be widely used in forestry discipline such as medicine plants under the forests, forest disease, breeding and forest ecology. For example under the canopy, Panax ginseng is famous for its medicine use (ginsenoside etc.) in roots. Considering the relationship of holographic law, its leaves, stems and flowers also have medicine value (ginsenoside etc.). This has been continued by pharmacological tests.

227 POPULATION VARIABILITY OF PINUS SYLVESTRIS L. KARYOTYPE IN THE SOUTH URALS

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Genetic structure and diversity of natural populations of P. sylvestris in the South Urals was studied with the aim of preservation of valuable gene pool.

Karyotype of P. sylvestris is relatively stable in the number (2n=24) and morphology of chromosomes. However, its profound study showes some intraspecific and even intrapopulation variability in a number of characteristics.

The studies of karyotypic polymorphism of P. sylvestris population, growing under contrast conditions, showed a considerable influence of extremity factor (high-mountain climate, natural isolation) on the increase of total length of diploid chromosome set, the rise of number and frequency of occurence of secondary constrictions and variability of morphometric chromosome characteristics.

High karyotypic variability inside populations, growing under extreme conditions, undoubtedly increases the range of their genetic plasticity and provides adaptability.

The given results are confirmed by the studies of genetic structure of these populations using enzymic markers and hemotype composition.

228 DIE-BACK OF AUSTRIAN PINE IN ISTRIA

Nikola Komlenović, Branimir Mayer and Petar Rastovski (Forest Research Institute, Jastrebarsko)

Forest damage survey in Istria (Western Yugoslavia) has showed that Austrian pine damage is more than 60%. The quantity of non-damaged trees (degree 0) was only 12% in the region of Labin (Eastern Istria) where is located thermo-electric power plant Plomin.

These investigations include 20 Austrian pine cultures. Chemical soil properties and nutrient concentrations in needles were analysed.Considerably higher sulpur concentration were found in Austrian pine needles and in top 5 cm of humus accumulative soil horizon in Labin region. This soil also contained the highest lead and zinc - concentrations.

229 ORGANOGENESIS AND PLANT REGENERATION FROM EXPLANTS OF MATURE CHESTNUT (*CASTANEA SATIVA* L.) TREES.

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In majority cases, micropropagation of tree species has been achieved with tissues of juvenile plants and very few reports are available where complete plant regeneration has been achieved with tissues of mature trees. In chestnut (*Castanea sativa* L.) too, plant regeneration has been reported either from young seedlings or juvenile plant parts. However, cloning of mature trees is generally preferred over cloning of embryos or seedlings because more than often it is not possible to determine if these will develop into true to the type plants. In this investigation, organogenesis and plant regeneration from explants of mature chestnut (*Castanea sativa* L.) trees was attempted and results obtained, so far, have been reported. Dormant as well as active axillary buds and shoot tips from 10 yr old plants were surface sterilized for 90 sec in 70% ethanol followed by 5 min dip in 10% calcium hypochlorite solution. After 3 washings in sterilized distilled water, 1-2 mm long explants were planted in different growth media and hormonal concentrations and were kept under 16 hr photoperiod (2.5 klx) at $22 \pm 2^{\circ}C$ unless otherwise mentioned. In White's medium, supplemented with BA 1 mg/liter + IBA 0.5 mg/liter, explants were successfully established and developed into microshoots having a whorl of 3-5 differentiated leaves covering a bunch of leaf primordia after 45 days of implantation.

230 THE EFFECT OF CHANGING LIGHT CONDITIONS ON LEAF STRUCTURE IN YELLOW BIRCH (*BETULA ALLGHANIENSIS* BRITTON)

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Yellow birch seedlings were grown (1+0) in pots over one growing season (n) under two different light conditions 1) full sunlight and 2) in shade (25% of full sunlight). At the beginning of the following growing season (n+1), prior to bud break, each set of seedlings was divided as follows: one half was transferred to the alternate light conditions while the other half was maintained under the same light conditions as in the previous growing season. Thus, four different light treatments were applied to the seedlings over the two year growing period.

Anatomical investigation made on the first cycle leaves (early leaves) harvested one week after leafing out (at the beginning of n+1 growing season), suggests that the structure of the mesophyll is primarily determined by the light conditions of the previous growing season (n). However, the anatomical organization of older first cycle leaves harvested four weeks after bud break shows that the current light conditions are responsible for the altered structure of the mesophyll. The characteristics of the second cycle leaves (late leaves) were also dependent on the light conditions of the current year (n+1).

Our results suggest that the sun and shade structures of the first cycle leaves are predetermined in the bud and influenced by the light conditions prevailing during bud formation. Our data indicate however that this structure is quickly modified by the current light conditions.

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DÉFICIENCES MINÉRALES LIÉES AU DÉPÉRISSEMENT DE L'ÉRABLIÈRE À BOULEAU JAUNE SUR LE BASSIN DU LAC CLAIR

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Durant la première semaine du mois d'août, trente-quatre érables à sucre ont été échantillonnés dans le tiers inférieur de la cime à environ 13,7 m de hauteur. Les échantillons de feuilles ont été séchés à 65°C durant une période de 72 heures. Puis nous avons séparé le pétiole du limbe que nous avons broyé à 10 mailles à l'aide d'une lame en téflon pour éviter tout problème de contamination. Les échantillons ont été minéralisés à l'aide de l'acide sulfurique 10% et du peroxyde d'hydrogène. L'azote est déterminé par colorimétrie alors que P, K, Ca et Mg sont analysés par ICP. Les résultats obtenus révèlent que l'azote, le phosphore et le potassium ont des valeurs moyennes de 2,29%, 1564 $\mu g.g^{-1}$ et 9504 $\mu g.g^{-1}$ respectivement, ce qui est nettement supérieur au seuil de déficience fixé pour chacun de ces éléments. Cependant, le calcium et le magnésium ont des concentrations moyennes de 4369 et 746 $\mu g.g^{-1}$, ce qui est nettement inférieur aux valeurs minimales nécessaires pour assurer un bonne croissance de l'érable. Ce problème nutritionnel semble associé à la pollution et aux faibles quantités de ces éléments dans le sol dues à la formation géologique qui est de type granitique et gneissique.

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EFFETS DES PLUIES ACIDES SIMULÉES SUR LA CROISSANCE DES SEMIS D'ÉPINETTE NOIRE, D'ÉPINETTE BLANCHE ET D'ÉRABLE À SUCRE

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Cinq traitements ont été sélectionnés pour évaluer les effets des pluies acides simulées en pépinière sur des jeunes semis d'érable à sucre et de résineux: pH 5,6 (témoin); pH 4,0; pH 3,5; pH 3,0 et pH 2,5. Nous avons tiré au hasard la séquence des traitements dans chacune des trois répétitions (blocs) établies. Les pluies acidifiées sont appliquées une fois par semaine durant la saison estivale (début juin, fin août) à l'aide du système d'irrigation de la pépinière. Les résultats obtenus à partir des mesures de hauteur et de diamètre au collet démontrent une augmentation de la croissance en hauteur pour les semis ayant subi des traitements à pH 4,0 et 3,5 comparativement au témoin. Cependant il y a une diminution de cette croissance pour les deux autres niveaux de traitement, soit pH 3,0 et 2,5. D'autre part, il y a des nécroses en abondance sur le feuillage de chacune des espèces étudiées à pH 2,5. Ces symptômes visuels sont difficiles à détecter à pH 3,0 et pratiquement absents pour les autres traitements appliqués.

233 EFFECT OF SOIL-AIR POLLUTANTS ON VEGETATION AT CERTAIN LOCALITIES OF HYDERABAD.

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ABSTRACT

The present paper aims in assessing the relationship between sulfur dioxide in the ambient air with soil sulfate and foliar sulfate. Nacharam - Moulali Industrial area of Hyderabad is being polluted by relatively high concentrations of Sulfur dioxide. Sulfur in the form of sulfate was found accumulated in the soil and plants growing around these industrial pockets. *Pithecolobium dulce*, *Nerium odorum* and *sida cordifolia* etc. were the plants which have shown maximum sulfate accumulation. There was a significant relationship between ambient SO_2 and foliar SO_4 accumulation.

Key words: Sulfur dioxide, soil sulfate, foliar sulfate.

234 PHYSIOLOGICAL QUALIFICATION OF SEEDLINGS: A NEW TOOL TO IMPROVE NURSERY CULTURAL PRACTICES

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Morphological parameters are routinely used for seedling qualification in nursery production. A cultural practice empirically used may be deleterious to seedlings without causing noticeable morphological changes. Physiological characterization of seedlings would be a better way for selection and evaluation of nursery cultural practices. The authors verified if monitoring carbohydrate tissue content (soluble sugars and starch) over the year can be a valuable indicator of seedling physiological activity and be related to specific phenological stages like bud break, active growth period, hardening and hibernal dormancy. Recorded annual patterns showed variations for specific families of carbohydrates throughout the growing period. Monitoring these compounds, which can be easily and precisely measured for all seedling species, will permit to evaluate man-made decisions in the process of seedling production, to select proper cultural practices, and, consequently, to plant seedlings of better quality.

235 APPROACHES TO HARDWOOD TREE IMPROVEMENT THAT YIELD BETTER TREE FORM

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Reforestation of hardwoods in Quebec is primarily aimed at the production of quality lumber and veneer. To achieve this goal tree improvement and adapted sylviculture practices must be used together. Tree improvement of species like Quercus rubra L., Fraxinus americana L. and Betula alleghaniensis Britton will concentrate on increasing the quality of individual trees. Quality defined here as tree form is dependent on the ability to maintain apical dominance and rapid growth until the height of the first butt log is reached. Climatic adaptation, cyclic growth, branch angle and response to light which are under varied degrees of genetic control, influence apical dominance or the ability to maintain a single leader. Hence, selection and breeding schemes will aim at manipulating tree morphology in addition to increasing the juvenile growth rate and climatic adaptation. Underlying hypotheses for schemes using interspecific and inter-provenance hybridization, mother-tree selection and clonal selection are presented here. How each component of a genetic improvement strategy can achieve such goals as better tree form will be discussed.

236 TROPICAL MOLLICUTE DISEASES

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Considerable progress has been achieved in the study of the physiology and ecology of spiroplasmas but MLOs, which cause most of the 300 known plant mollicute diseases have not yet been cultured. Sensitive probes to distinguish MLOs are now employing gene cloning and hybridoma technology. Most spiroplasmas and MLOs require alternating plant and insect vector hosts for their maintenance in nature. Probably they originated as arthropod pathogenes and during evolution became adapted to plant hosts. While vector control in the tropics is seldom successful, breeding for resistance to molliculites and to vectors has given good results. Chemotherapy has been disappointing. Certain mollicute diseases have responded to heat treatment and surgery and screens have been used to prevent vector transmission in selected instances. Cross-protection and new biotechnology approaches to vector control, as well as wider application of inexpensive integrated control employing neem products promise to diminish crop losses in the tropics.

237 SELECTIONS OF SPECIES, ORIGINS AND PROCEDENCE OF *EUCALYPTUS*, RESISTANT TO LOW TEMPERATURES IN NURSERY PLANTS FOR THE NORTH OF THE SALADO DEPRESSION, BUENOS AIRES PROVINCE, ARGENTINE.

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Considering the resistance to low temperatures, an early selection in tree nursery plant of 55 origins and procedence of Eucalyptus was made.

The damage produced by frost hapenned in Lobos (35°10' LS Long W 59°, 29 m.s.n.m.), Buenos Aires Province on (plantines) seetling of *Eucalyptus camaldulensis*, *E. tereticornis*, *E. viminalis*, *E. ovata*, *E. dunnii*, *E. delegatensis*, *E. nitens*, *E. E. fastigata*, *E. elata*, *E. smithii* y *E. oreades*, was also analysed.

A completely aleatory design was made with 10 repetitions in 24 plants each one. A damage scale of 0 (undamaged) was settled, to 5 (air part dead); whole heights were taken at ten months to measure vigor; these evaluations were tested by Tuckey so as to compare media.

The heights of plants and the damage with the Geographic parameters of each origin were correlated. A high positive correlation with latitude, altitude and resistance to frost appeared.

Eucalyptus camaldulensis of higher latitudes specially Lake Albacutya; *Eucalyptus tereticornis* of similar latitudes around 29° LS; *Eucalyptus viminalis*, all the origins proved, *E. ovata*; *E. delegatensis*, *E. fastigata* and *E. dunii* were outstanding because of their behaviour.

238 EFFECTS OF SHADING ON THE GROWTH OF *FAGUS CRENATA*, *QUERCUS CRISPULA* AND *Q.SERRATA* SEEDLINGS.

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The growth of seedlings of *F.crenata*(Fc), *Q.crispula*(Qc) and *Q.serrata* (Qs), which are among representative tall deciduous tree species of summer-green forest in Japan, were studied for 4 years under different relative light intensities(RLI, 10,15,25,75&100%). A marked difference in seedling height, diameter and net production(NP) were observed among three species. in turn of Qs > Qc > Fc, both under shading and control plots. The differences in NP were estimated to have been resulted not from the leaf efficiency but the leaf amount. The differences in leaf amount depend upon the total shoot length rather than the number of leaves per unit shoot length. These traits seem to show the life strategy of these three species. The common pattern of these species of height and diameter growth varied with RLI and the amount of growth increased with increasing RLI. The degree of growth reduction under heavy shade was Qs > Qc ≫ Fc. This trend was more clear in 2-year-old seedlings than 4-year-old. Shade tolerability are the most prominent in Fc, which is considered as a climatic climax species, followed by Qc, which as a edaphic climax species, and the least in Qs, which as a dominant species of secondary forest.

239 DEPOSITION OF AIR POLLUTANTS IN THE GERMAN SOLLING AREA: EFFECTS ON SOIL CHEMISTRY

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Quantitatively most important deposition compounds in the Solling area are S, N and H^+, long term deposition rates reaching as much as 80, 45 and 3.8 kg $\cdot$ ha^{-1} $\cdot$ a^{-1} in case of spruce. Sulfur deposition seems to be decreasing slightly since about 1980.

The soils of the Solling area are generally very acid, $pH(CaCl_2)$ ranging from 3.0 to 4.1 and base saturation in less than 5%.

Soil solution chemistry is dominated by Al and H^+ as cations and SO_4^{2-} and NO_3^- as anions.

Al-concentrations increase with soil depth and reach long term average values of 13.5 mg/l at a depth of 80 cm under spruce and of 3.6 mg/l under beech. Sulfate being the most dominant anion. However, nitrate concentrations in the top soil are highly variable due to the internal nitrogen cycle of the ecosystem and cause strong variation of the Al levels of the soil solution within the main rooting zone.

Soil chemical stress parameters like Ca/H, Ca/Al and Mg/Al-ratios show pronounced gradients, Ca/Al and Mg/Al ratios decreasing with depth. The temporal development of these stress parameters is characterized by strong variation in the top soil.

Presently the acidification of the deeper soil layers has already proceeded to a depth of more than 2.2 m and is driven mainly by sulfate transport.

240 TERMITE CONTROL IN FOREST ESTABLISHMENT USING CONTROLLED RELEASE CARBOSULFAN

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Establishment of forests has a high priority in many countries in order to meet the increasing demand for fuelwood, industrial products, and environmental protection. *Eucalyptus* and *Acacia* predominate, both genera containing species susceptible to attack from subterranean termites, particularly during the establishment period after planting out in the field. Damage caused by termites occurs on the roots, underground stems and bark, all of which can lead to reduced growth and tree death. Evaluation of controlled release granular carbosulfan for termite control in tropical forestry commenced in 1985, aimed at finding an environmentally acceptable alternative to the use of the persistent organochlorine insecticides. The first field trials, in South Africa and Zimbabwe, showed that a single application of controlled release carbosulfan can provide up to two years' protection from termite attack, at a level of control similar to that obtained using organochlorine insecticides. Application of granules can be made either at planting in the field or to the potting soil in the nursery prior to potting up and subsequent planting out. In both cases thorough incorporation of granules in the treated soil is recommended in order to establish an effective protective barrier around the root zone. Controlled release granules are dry and dust-free and are of relatively low toxicity to users. Carbosulfan and its metabolites are non-persistent. Use of this formulation will therefore result in no persistent chemical residues in the environment.

241 IMMISION OF HEAVY METALS Pb, Cu, Zn INTO FLOODED FOREST SOILS

Branimir Mayer (Forest Research Institute, Jastrebarsko)

The most valuable lowland English oak forests in Croatia (north-western Yugoslavia) are already heavily damaged (38%). Susceptibility of forest soils to flooding with polluted water contributes to disrupting the stability of these forest ecosystems.

These investigations include 4 forest regions with 21 microlocation with samples from top 5 cm of humus-accumulative horizon.

Flooded forest soils have consideraby higher content of Pb, Zn and Cu than the non-flooded.

The accumulation of the investigated heavy metals in flooded forest soils represents additional anthropogenic influence which increases stability disruption of lowland forest ecosystems.

242 TEMPORAL VARIATION IN NATURAL INBREEDING IN A *PINUS MONTICOLA* POPULATION: EFFECTS ON SEEDLING MORPHOLOGY AND PARENTAL RANK

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Y.A. El-Kassaby (Canadian Pacific Forest Products Ltd., Saanichton, B.C.)

Evaluation of parent trees using their open-pollinated progeny is common in tree-improvement programs. Although western white pine (*Pinus monticola* D. Don) is fairly tolerant of selfing, such progeny generally grow poorer than those from outcrossing. Strong differences in estimated inbreeding by cone parents in a single stand were found for three successive cone crops, using isozyme techniques on seeds. The effects of these differences on 2-year family height, dry weight and growth distribution, and on family rank, are assessed.

243 NEW DEVELOPMENTS IN BOXPRUNING IN FLANDERS (BELGIUM)

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Most forest regeneration in Flanders is done by small to medium size forest owners who possess over 70% of the forest area. Reforestation is for over 90% done by artificial regeneration. The use of appropriated provenances or clones is becoming common. The applied reforestation techniques however are still rather underdefined and inextensive. Very few attention is given to site preparation, characteristics of planting stock, planting and to the follow up. This lack of organisation leads to failures on the field and demotivation of the forest owners. As part of a research programme with the aim of providing forest owners with an effective, easy to use and cheap planting system, different stock types for coniferous trees where tested.

Special attention was given to boxpruning applied to bare root plants in the nursery. Roots are pruned in three dimensions i.e. horizontal and vertical (in and between the lines). The horizontal pruning is carried out by a normal nursery pruning or lifting device. The pruning in vertical direction however is not possible if the plants are randomly dispersed on the seed-bed. The seeds need to be locate in a strictly perpendicular way. Existing devices for precision seeding are not accurate enough or uneasy to handle on the field. In cooperation with ICI SEEDS-SES N.V. a seedfoliage for direct application on the field was developed. The distribution of the seeds can be completely organised as desired.

Different pruningtypes where compared. Height, diameter, shoot and root dry weight, Root Growth Potential an root structure where evaluated. Boxpruning turned out to give different advantages over traditional and container stock.

* Research carried out with the aid of the I.W.O.N.L.

244 PRELIMINARY RESULTS OF CLONAL FIELD TESTS OF NORWAY SPRUCE IN FRANCE.

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A selection programme of Norway spruce was engaged in 1976 by AFOCEL in France with the goal to produce clonal varieties regionaly adapted for reforestation. The programme based on early mass selection mainly for vigour lead to plant clonal tests on different sites.

The poster gives results for clonal tests after 3, 6, 9 growing seasons in the field. The clone x site interaction and the influence of serial propagation are studied at the level of vigour and density estimated by penetromer technics.

245 INFLUENCE OF ACID DEPOSITION ON ELEMENT CYCLING IN MATURE SUGAR MAPLE FOREST, ALGOMA, CANADA

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Distributions of organic matter and macro-elements were determined in the tree- and field-layer, forest floor and mineral soil of an old-growth sugar maple (*Acer saccharum* Marsh.) forest, on a shallow, Precambrian-derived till soil at Turkey Lakes Watershed, Algoma District, Ontario. Gross biomass increment was estimated at 12.2 tonnes/ha/yr. Annual growth was largely offset by mortality, resulting in a relatively stable standing stock of *ca* 240 tones/ha. Annual aboveground litter production averaged 3.7 tonnes/ha/yr, mainly of deciduous leaf-fall. Mean annual volume-weighted pH of precipitation was 4.3. The acidity of precipitation was reduced considerably by contact with the forest canopy. Throughfalls were enriched with other elements, principally K and to a lesser extent with Ca and Mg. This varied between growing and dormant seasons. The cationic composition of forest floor percolates, on the other hand, was dominated primarily by Ca and only to a lesser extent by Mg and K. Streamwater pH was near neutral in the deeper soil areas and was dominated by Ca, SO_4^{2-} and NO_3^- ions. The stand receives moderate acid deposition, mainly wet, with average inputs of 23.6 kg/ha/yr of wet SO_4^{2-} and 16.8 kg/ha/yr of wet NO_3^- distributed throughout the year. Atmospheric inputs add to substantial natural NO_3^- production, primarily within the forest floor and upper mineral soil, and contribute to leaching of bases, principally Ca and Mg from the rooting zone. Annual inputs and leaching losses are compared with amounts estimated to be cycling annually.

246 ARTIFICIAL SCREENING TEST FOR HYBRID POPLAR RESISTANCE TO *SEPTORIA* CANKER IN QUEBEC

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Septoria musiva Peck (teleomorph *Mycosphaerella populorum* G.E. Thompson.) is a widespread pathogen causing leaf spots and cankers in hybrid poplar plantations in southern Quebec. This fungus represents a threat four future reforestation programs with high-yield susceptible poplars. We used an artificial screening test to accelerate the evaluation for resistance of more than 1 000 clones. Since 1986, artificial inoculation tests have been conducted in the nursery with several isolates of *S. musiva*. This technique allows an easy and rapid preliminary screening in a single growing season for a great number of clones. Differences among species and among hybrids have been observed. Clones that seem less susceptible are mostly in the groups of *Populus* x *euramericana* and *Populus deltoides*. Clones with *P. trichocarpa* and *P. maximowiczii* parentage were the most susceptible.

247 POPULATION DYNAMICS OF *SEMANOTUS JAPONICUS* IN ASSOCIATION WITH RADIAL GROWTH OF THE HOST PLANT

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Sugi bark borer, *Semanotus japonicus* Lacordaire, is one of the most serious pests of Japanese cedar, *Cryptomeria japonica* D. Don, which is widely planted for timber production throughout Japan. Unfortunately, we do not have an effective method for controlling the insect. In the research, the relationship between population dynamics of the sugi bark borer and radial growth of the tree is explained. Trees infested by the insect were cut down in 6 stands, and then pupal chambers and annual rings in the stem were examined. The percentage of trees infested was also determined together with the radial growth in 12 stands. Annual fluctuation pattern of the number of sugi bark borers was characterized with one peak which occurred in the 10-20 year-old stands. Establishment of the sugi bark borer into the stand occurred around the time of maximum width of annual ring at breast height. Infestation by the insect rapidly spread over the stand on the increase period of the insect population. The insect abundance on both tree and stand level had positive correlation with the width of rings on the increase period of the insect population. In conclusion, pruning branches from trees during the increase period of the insect population would be an effective method for controlling the sugi bark borer.

248 CORRELATION BETWEEN MORPHOLOGICAL CHARACTERS AND WOOD DENSITY FOR EUCALYPT HYBRIDS.

Oda, S., Feddersen Jr., A., Menck, A.L.M. (Cia. Suzano de Papel e Celulose)

Experiments with opened and controlled polinization demonstrated intermediarism in the wood density for hybrids. Hybrids of *E. grandis* x *E. camaldulensis* from opened polinization could be separated in four classes (types) by the likelihood of the morphologicals characters. It was obtained a high positive correlation between morphological classes and wood density (R = 0,92). This result suggests others researchs in hibrid breedings programs and homogeneity for wood quality.

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LIFE CYCLE OF CONTORTYLENCHUS SP. ASSOCIATED WITH THE JAPANESE PINE SAWYER BEETLE

Ogura, N. and Kosaka, H. (Forestry and Forest Products Research Institute, Tsukuba, Japan)

Nematodes which parasitize ovary and testis of the Japanese pine sawyer beetle, *Monochamus alternatus*,have both parasitic cycle and mycetophagous free-living cycle. Female adult nematodes lay eggs and the 2nd stage juveniles which hatched from the eggs develop to the 4th stage juveniles within reproductive organs of the adult beetles. The 4th stage juveniles leave the beetles at oviposition and defecation, and molt to male or infective female adults under existence of the larval beetles. The 4th stage juveniles also molt to male or mycetophagous female adults, and propagate on mycelia of the fungus which was isolated from the juveniles but not identified yet. Infective female adults also arise among the mycetophagous nematodes under existence of the larval beetles, and infect the beetles. Heavy infection of the nematodes completely destroy ovary and testis of the adult beetles.

The nematode was grouped to *Contortylenchus* sp. mainly from the forms of both infective female adult and mature female adult within the adult beetles.

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ALLOMETRIC RELATIONS OF LEAF AREA FOR YELLOW BIRCH (*BETULA ALLEGHANIENSIS* BRITTON).

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Total leaf area is an important parameter in estimating carbon, solar energy and water fluxes of forest ecosystems, because leaf area can be directly related to net photosynthesis, light interception and transpiration in tree canopies. To quantify the various fluxes in northern hardwood stands, thirty-five birches were sampled in the Duchesnay region, near Québec City, Canada. The trees were all dominant individuals in stands of various ages. Results show that, as expected, leaf area index (LAI) is related to total leaf area, as well as to other morphological parameters (stem diameter, width of crown, height of morphological inversion point, etc.). A more detailed analysis for different levels in the crown reveals a difference between short and long detailed twigs for total and specific leaf areas.

251 NUTRIENT STATUS CHANGES OF DECLINING SUGAR MAPLE STANDS AS INFLUENCED BY FERTILIZATION

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Québec, Canada

The decline of sugar maple (Acer saccharum Marsh.) has been observed in all its geographical distribution in the province of Quebec. Foliar analysis of 307 stands sampled over this area in 1988 has shown that potassium, phosphorus, or magnesium deficiencies are associated with forest decline. The specific deficiency that occurs depends on the nature of the soil and parent material. Diagnostic fertilization of these sites to replace nutrients identified as deficient has improved the nutrient status of these stands and has leaded to healthier trees that can withstand other stresses. Although fertilization has a positive impact on maple stands and provides a mean to revitalize declining trees, sources of stress that caused imbalanced nutrition remain unknown. Soil, humus, and ecological type are parameters examined in relation to forest nutrition status.

252 OPERATIONAL ROOTING OF JUVENILE CUTTINGS OF CONIFER AT THE SAINT-MODESTE NURSERY.

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In 1989, an important program of operational rooting of conifer cuttings was undertaken at the "pépinière forestière de Saint-Modeste" for bulk-propagation of juvenile plants from full-sib families of black spruce, Norway spruce, white spruce, jack pine, and larch. All year-round growth of the seedling ortets in greenhouses allows continuous production of cuttings. Rooting is performed in a confined environment under artificial conditions. Rooting facilities consist of six sets of four-storied shelves located in a temperature-controlled room and lighted with fluorescent lamps. Each story supports a polyethylene mini-greenhouse of 29 m^2. This compact system is unique by using a controlled environment for rooting with low light intensity (30-50 $\mu mol.s^{-1}.m^{-2}$) and without the requirement of constant misting. One million stecklings can be produced annually in 4-5 productions with the existing propagation area. Rooting in more compact containers will increase the production to 5 million a year.

253 PROTEIN METABOLISM AND PATTERNS DURING SOMATIC EMBRYOGENESIS OF HYBRID LARCH (*LARIX* x *EUROLEPIS*).

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Induced embryogenic cell lines of hybrid larch (*Larix* x *eurolepis*) were sampled at various stages during embryogenesis up to the appearance of embryos for enzyme activities and protein patterns. For the 10 enzymes selected, activity generally increased slightly during the first 15 days of embryogenesis, then gradually decreased. Comparison of embryos and supporting callus tissues showed much higher activity levels for both proteins and all 10 enzymes in embryo tissues. There were also differences in some protein bands between the two types of tissue. Analyses of total protein on one-dimensional and two-dimensional SDS-PAGE showed a general decrease not only in the amount of protein but also in the number of protein species, along with progress of embryogenesis on the induction medium. The calli, too, changed greatly in appearance before formation of embryos on the induction medium.

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254 Are Black Spruce Cone and Seed Insects Threatening Forest Regeneration?

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The seasonal damage to female reproductive structures (buds, flowers, and cones) of black spruce (*Picea mariana* [Mill.] B.S.P.) was assessed in 1983 and 1984. Nineteen insects (five orders) and the red squirrel (*Tamiasciurus hudsonicus*) were found feeding on these structures. Collectively, these organisms damaged 88.9 and 53.5% of the cones in 1983 and 1984, respectively. Lepidoptera damaged 61.8% of the cones in 1983 and 44.4% of the cones in 1984. The spruce budworm (*Choristoneura fumiferana* [Clem.]) and the spruce coneworm (*Dioryctria reniculelloides* Mut. & Mun.) were the most important pests. Cones damaged by Lepidoptera could be classed in three categories: (a) severely damaged, yielding no seeds; (b) moderately damaged, yielding 22.3 seeds per cone; and (c) lightly damaged, yielding 37.5 seeds per cone. Undamaged cones yielded on average 39.9 seeds per cone. Red squirrels removed 18.8% of the cones in 1983 and none in 1984. The spruce cone axis midge (*Dasineura rachiphaga* Tripp) and the spruce cone maggot (*Strobilomyia neanthracina* Michelsen) caused minor damage in both years. Feeding by the spruce cone axis midge did not significantly reduce cone growth or the number of viable seeds per cone, but feeding by the spruce cone maggot did. In both years, new damage by insects to the female reproductive structures of the experimental trees was not observed after mid-July. In 1983, damage by red squirrels occurred from early to late September. In 1984, damage to cones on trees treated with dimethoate amounted to 15.6% in comparison with 53.5% on untreated trees, and there was no increase in the number of aborted cones on the treated trees.

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DIFFERENTIATION OF LARIX SUKACZEWII IN THE SOUTH URALS

Putenikhin, V.P., and Ishbirdin, A.R. (Botanical Garden, Bashkir Sci. Centre, Ural Division Acad. Sci. USSR, Ufa, USSR)

Larix sukaczewii Dyl. in the South Urals was studied using 22 quantitative and 7 qualitative characteristics of generative organs by principal component analysis, estimation of Mahalanobis distances and repeatability of characteristics. This species was shown to be differentiated into several local populations in this region: Central South Ural, High-Mountain South Ural, Marginal Ural, Bashkir Pre-Ural. Pre-Ural population, represented by small isolated stands, has the lowest phenotypic and genetic variability. The population in extreme high-mountain conditions is characterized by higher genetic heterogeneity. Communities of the High-Mountain population of larch are characterized by considerable diversity of species composition. They include, for example, periglacial Pleistocene relics (Pentaphylloides fruticosa, Swertia obtusa) and Arctic-Alpine species (Polygonum viviparum, Pedicularis oederi).

On the basis of population-genetic and phytocoenotic estimation of differentiation of larch 7 genetic reserves were established at the area of 4570 ha. There are created interpopulational seed orchards; micropropagation technology for reproduction of larch populations are being developed.

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SEASONAL CHANGES IN THE AMINO ACID AND TOTAL PROTEIN STATUS OF NEEDLES TREATED WITH ACID RAIN

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Seasonal changes in amino acid pools and total protein content were studied in needles of Scots pine (Pinus sylvestris L.) and Norway spruce (Picea abies L. Karst.) seedlings subjected to acid rain irrigation. Sampling was planned to follow cold hardening in order to observe changes in cryoprotective substances. Simultaneous samples were taken for transmission electron microscopy. The total protein content of the needles varied seasonally, being at its minimum in autumn, increasing until February, and decreasing again in spring. The seedlings treated with pH 3 irrigation had lower protein levels than the untreated control seedlings. Arginine content increased from 25-45 nmol/g fresh weight to in maximum 425 nmol/g fresh weight from September to December, whereas glutamine, glutamate and GABA decreased at this time. The acid rain treatments increased the proportion of N-rich amino acids such as arginine, glutamate and glutamine in the spruce needles, followed by a decrease in β - and γ - aminobutyric acid content. An increase noted in the numbers of membraneous folds seen in the needle mesophyll cells under electron microscope is compared to the active protein synthesis during the hardening period.

257 RESEARCH ON DIEBACK OF SUGAR MAPLE STANDS IN QUÉBEC

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In Québec, dieback appeared on hardwood species in the early 1980's. Limited at first to the Appalachian region, dieback has affected the whole deciduous forest since 1985, that is an area of 24 000 km^2. In view of the dimension and severity of the phenomenon, research was initiated to determine its causes and eventually to propose appropriate remedies. A network of 133 semi permanent sample plots was established and 75 environmental variables were measured and observed on a 5-year period. A multivariate analysis showed the variables most susceptible to cause dieback. Results did not permit to detect a single factor which would explain the phenomenon and also confirm the hypotheses of Manion (1981) and Dessureault (1986). However, these results retain 36 variables grouped into four categories of explaining factors. Two of them constitute predisposing factors which are associated with habitat and vigor of the stand. The two others imply climatic variations and ionic unbalance of forest soils; they constitute contributing factors. In order to qualify and quantify the effect of these factors on dieback, dendrochronological and anatomical researches are going on.

258 PLASTICITY OF LEAF ABSORPTANCE IN TREE SEEDLINGS.

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Controversy still prevails on the importance of previous year light conditions on morphological and physiological characteristics of current year leaves. While some works revealed strong predetermination in the buds, others didn't. In fact, leaf plasticty seems to be related to the species shade tolerance. This study was undertaken to compare leaf absorptance plasticity in seedlings from five broadleaf tree species of various degree of shade tolerance. In spring, prior to leaf emergence, fifteen seedlings from each species exposed to a high light regime during the previous summer were placed under a dense forest canopy while fifteen others were left in the open. Leaf absorptance in the 400-1100 nm waveband was measured on each seedling (2 leaves per seedling) following full leaf development (early June), and prior to leaf senescence (late July). The same leaves were sampled at both times. In early June, the highly shade tolerant *Acer saccharum* already showed significant differences in leaf absorptance of its shaded and sunlit leaves. In this species, light conditions at time of budbreak seem to have greater effects on leaf physiology than light conditions prevailing during formation of leaf primordia. Leaves of mid-tolerant *Quercus macrocarpa*, *Fraxinus americana* and *Betula alleghaniensis* responded less quickly to shade, with absorptance differences appearing later in summer. As for the intolerant *Juglans cinerea*, the weak differences in absorptance measured between its shaded and sunlit leaves in late July let presumed a low physiological plasticity in its seedling leaves.

259 SUSCEPTIBILITY OF EUCALYPTS TO CYLINDROCLADIUM LEAF BLIGHT DISEASE IN KERALA, INDIA

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In detached leaf inoculations, susceptibility of 65 eucalypt provenances (belonging to 16 species of Eucalyptus) to Cylindrocladium leaf blight (CLB) caused by Cylindrocladium clavatum (CC), C. ilicicola (CI) and C. quinqueseptatum (CQ) differed significantly. Differences also occured among the provenances of an eucalypt species to a particular Cylindrocladium species. Often susceptibility of a provenance to various species of Cylindrocladium also showed significant differences. There were only a few provenances which were either equally resistant (E. tereticornis 12944, 13277, 13319 and E. tessellaris 12967 or susceptible (E. urophylla 12896 and E. camaldulensis 12964) or highly susceptible (E. cloeziana 13278) to all the three species of Cylindrocladium. Among the three species, CC was the most virulent, CI the least and CQ intermediate. A wide range of pathogenic variability was observed among five isolates of CQ, selected out of 60 isolates, which could be distinguished as different physiologic strains on 11 differential provenances of Eucalyptus. Susceptibility ranking of different provenances to five isolates differed significantly indicating differential interaction between isolates and provenances. Analysis of variance showed that CLB severity of a provenance is mainly governed by the genetically different isolates and also that the provenances have closer genetical relationship. The results provide the first evidence for the existence of physiologic strains in C. quinqueseptatum.

260 ROLE DES POLYPHENOLS DANS LE PHENOMENE DU DEPERISSEMENT DES ERABLIERES DU QUEBEC

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Le dépérissement des érablières est habituellement interprété comme résultant d'une situation de stress; que ces stress soient de nature climatique ou édaphique, ou dus à des facteurs polluants, cette situation entraîne actuellement une perturbation de tout l'écosystème forestier. L'auteur montre que les plantes répondent à de tels stress par une synthèse accrue de composés phénoliques, lesquels jouent un rôle "protecteur" constituant ainsi une adaptation du végétal. De plus, on a observé qu'à une quantité importante de ces composés dans les feuilles tombées à l'automne (>40% du poids sec) est associée une faible activité biologique du sol. Cette grande abondance des composés phénoliques pourrait ainsi expliquer en partie la perturbation du cycle biogéochimique déjà constatée dans ces sols. L'auteur propose également une mise au point d'une méthode de dosage des polyphénols, ainsi qu'une interprétation physiologique du métabolisme de ces composés dans le phénomène du dépérissement des érablières.

261 THE PROBLEMS OF FOREST DIEBACK IN ALPINE PARKS - ON THE EXAMPLE OF TRIGLAV NATIONAL PARK

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There are four extremely important goals we are trying to reach in our research: Forest health assessment, the causes of forest dieback, its consequences and sanation of it. The official forest dieback assessment methodologies are often not corectly usefull in the various alpine region. Special attention is to be paid to the selection of referential trees, to the thorough analysis of correlation between forest dieback situation and the physical conditions of the ecosystem such as altitude, exposition, water regime and soil. The second type of correlation is between the forest dieback and the forest stands condition (age of the forest, stand structure etc.).

We are supposing that there are no visible symptoms of direct influence of polluted air (except photooxidants) on forest in Triglav National park. The indirect effect of polluted air is linked with climatic changes. The moisture - temperature stress is considered to be the most important trigger of decline in the Triglav national park forests.

The past and present human influence should be included in analyses.

262 CORRELATION BETWEEN SILVICULTURE AND TRUFFLE PRODUCTION

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Truffle production has always arisen a strong interest, due to the high economic return, though it is today decreasing.

Possibilities of increase are related to the creation of forest stands with plants previously mycorrized with various species of *Tuber*.

Production of this material require special knowledge of truffle biology, exposed as a starting point for a correct use of safe nursery practices in mycorrized plantlets production.

A description of ecological characteristics of natural sites for mycelia of valuable *Tuber* is given.

Particularly traditional and new techniques of mycorrized plantlets production have been given.

Some of the most appropriate agricultural practices to cultivate the various associations truffle-plant are shown.

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OAK DECLINE IN AUSTRIA

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Oak decline in Austria was first reported in 1983 in oak stands close to the Hungarian border. Most affected are *Quercus robur* and *Quercus petraea*, whereas *Quercus cerris* and *Quercus rubra* seem not to be affected. Symptoms occuring are translucent crown, chlorosis and stem necrosis, abortion of twigs, bark cankers on branches and stem. Detailed studies showed a high percentage of *Armillaria* rot in diseased trees. In addition Scolytidae, Buprestidae and Cerambycidae could be found on weakened oaks.

Out of samples of twigs and trunks of white oak showing oak decline symptons, sap wood nematodes (*Bursaphelenchus* spp.) could be isolated in large numbers. Density of nematode attack seems to be correlated with the severity of oak decline. At present pathogenity tests are being carried out.

A period of very little rain fall and long lasting dry periods between 1975-1983, ground water problems and extremely low winter temperatures down to -31°C without snow cover are considered main factors of oak decline in Austria.

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PHYSICO-CHEMICAL CHARACTERISTICS OF *PINUS SYLVESTRIS L.* NEEDLE SURFACES AFTER LONG-TERM ACID RAIN TREATMENT

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A natural stand of adult *Pinus sylvestris L.* was exposed to pH 4.0 and pH 3.0 simulated acid rain in the extreme north of Finland during the period 1985-1989. By the end of this period, the pH 3.0 treated pines had received a sulphur load of 7.48 g m^{-2} and a nitrogen load of 2.62 g m^{-2} and the pH 4.0 treated pines a sulphur load of 1.23 g m^{-2} and a nitrogen load of 0.43 g m^{-2} in addition to ambient deposition. No visible symptoms of acid rain injury were observed in the needles, but development of the needle epistomatal waxes was delayed and disturbed. Four types of deformed stomata: narrow, half-formed, occluded and double-sized were found in the scanning electron microscopy. The mean of total number of deformed stomata in pH 4 treated pine needles during the experimental period was 51 % greater when compared either to water or dry control pines. Fast erosion of young undeveloped waxes increased needle wettability after acid rain treatment, but the concentration of chloroform soluble waxes was only slightly decreased. The effects of acid rain on epicuticular waxes were accentuated during and after unfavourable growing seasons with reduced effective temperature sums.

265 LOBLOLLY PINE SOMATIC EMBRYO DEVELOPMENT AND MATURATION

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Initiation of somatic embryogenesis in loblolly pine (Pinus taeda) has been obtained in several laboratories and has become a more straightforward process. Development and maturation of somatic embryos, however, remains a serious obstacle to use of the process as a low-cost, rapid means of clonal propagation. Recent experiments indicate that manipulation of carbohydrate source and levels as well as concentrations of abscissic acid and indole-butyric acid and the timing and duration of exposure to them markedly influence development. Small but significant numbers of cotyledonary somatic embryos have been obtained that closely resemble, morphologically and anatomically, their zygotic counterparts. Trials testing various media for somatic embryo germination and conversion to seedlings are in progress.

266 ALLELOPATHIC EFFECTS OF TROPICAL TREES (ACACIA, DERRIS AND EUCALYPTUS) ON SEEDLING VIGOUR OF SOME FIELD CROPS

[illegible]

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Allelopathic effects of (1) Acacia auriculiformis, (2) Derris indica and (3) Eucalyptus 'hybrid' and the soils from the plantations on finger millet, soybean, french bean, cowpea and sunflower were tested. There were differential effects of soils on germination and seedling vigour in field crops. Methanolic root, stem, leaf and leaf litter extracts of Derris and Eucalyptus differed in overall inhibition. The leaf and litter extracts of Eucalyptus [illegible] affected germination of [illegible] crops. Seedling vigour was reduced by [illegible] extracts [illegible] of both species. Effects were proportionate to the concentration of the extracts. The possibility of adopting agroforestry practices are discussed in the light of the results obtained on the residual allelopathic effects in the soils. The nature of allelopathic effects and the principles are being investigated.

267 ASSESSMENT OF PHOTOSYNTHESIS AND ATTRIBUTES IN TROPICAL TREE SPECIES DIFFERING IN BIOMASS PRODUCTION POTENTIAL

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Photosynthesis(A) conductances(gs) and transpiration(E) rates in five tropical trees - *Acacia auriculiformis*, *Casuarina equisetifolia*, *Derris indica*, *Eucalyptus* 'hybrid' and *Grevillea robusta* - differing in biomass production differed significantly. *Acacia*, *Eucalyptus* and *Grevillea* exhibited high 'A' values. However, *Grevillea* was followed by *Eucalyptus*, *Casuarina* and *Acacia* in gs. Lowest values were in *Derris*. E values also differed significantly. There were also significant differences in chlorophyll contents, soluble protein and carbonic anhydrase activity. The results obtained are discussed in the light of variation in the biomass production potential.

268 ACCUMULATION OF BIOMASS OF HYBRID WILLOWS IN DIFFERENT REGIONS OF EUROASIA

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The choice of high productive clones of woody plants is of great importance when creating minirotation plantations.

Among 36 clones of hybrid poplars and willows which were examined in field trials and by methods of early diagnostics there were chosen the most perspective ones both in productivity and adaptability.

3 clones of hybrid willows (*Salix alba* x *S. fragilis*) selected by high productivity, were tested in Ukraine (50° n.l.), in Bashkiria (54° n.l.) and in the Korean People's Democratic Republic (KPDR) (39° n.l.). All three regions differed in biomass yield, but there wasn't found direct correlation of yield with climatic conditions. Biomass yield of plants, which were grown in Bashkiria, was 18-20 t/ha of oven-dry mass, those in Ukraine - 10-12 t/ha (in both cases plantations were 4 years old). In the KPDR 40-45 t/ha of oven-dry mass were produced during the first year.

Such difference in accumulation of biomass can't be conditioned only by climatic factors. Probably under certain conditions genetic mechanisms, providing maximal manifestation of hybrid power in plants begin to work.

269 STUDIES ON GENETIC STRUCTURE, MORPHOMETRIC VARIATION AND CARBON ISOTYPE COMPOSITION IN *Castanea sativa* POPULATIONS IN TURKEY

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European chestnut (*Castanea sativa* Mill.) has a greatly important role in Turkey. Moreover, this country is one of the supposed main centres of origin of this species. Studies on its genetic variability in this area have, therefore, a great biological relevance for the safeguarding and development of under-exploited genetic resources of chestnut.

Previous studies, based on isozyme analysis (VILLANI *et al*., 1990) have shown a high degree of genetic differentiation between western and eastern populations of Turkey. Such differentiation seemed to be partially correlated with some ecological factors such as rainfall levels.

Samples of *C. sativa* fruits have been collected from six populations in Turkey chestnut areas in order to confirm the validity of such findings at distinct ontogenetic stages and to explore the variation at different levels of biological diversity.

On each fruit, electrophoretic analysis at fifteen enzyme loci and morphometric measurements of twelve traits have been carried out. Carbon isotope discrimination was studied on the same samples in order to detect variation of transpiration efficiency.

Genetic variability and differentiation were estimated by Nei's standard genetic distance values (D). Uni- and multivariate analysis was also used to determine the morphological and physiological variation patterns in comparison with the genetic results. Correlation with some environmental parameters was also attempted. The preliminary results seem to confirm the differentiation observed at the adult stage between the western and eastern part of Turkey.

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270 Investigation and mapping of forest disease by passive remote sensing

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The main object of the project "Investigation and mapping of forest disease by passive remote sensing" advanced by the german ministery of research and technology was the development of operational methods for the monitoring and mapping of forest disease by airborne multispectral scannerdata.

The investigations were based on the data of 10 testsides in the Federal Republic of Germany Since 1986 the DLR was responsible for the dataacquisition by an airborne scanner in these testsides, in cooperation with different forestry universities and private companies. Objects of investigations were mainly spruce (picea abies), pine (pinus sylvestris), beech (fagus silvatica) and oak (quercus petraea).

With respect to future applications it is intended to develop operational methods for mapping forest disease by satellite data (e.g., Landsat TM, Spot).

In a first step the evaluation of Landsat TM satellite data revealed the possibility to differentiate 5 main classes: coniferous forest, deciduous forest, mixed forest, reforestation and blanks.

The results of the Maximum-Likelihood-Classification of airborne and satellite multispectral scanner data will be presented.

271 CHARACTERISTICS OF ECOPHYSIOLOGY OF *Pinus koraiensis* PLANTATIONS

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A 28-year-old *Pinus koriaensis* plantation in Laoshan Mountain Ecological Station of the Northeast Forestry University was tested. The photosynthesis and respiration of chlorophyll in different parts of the trees and layers of the canopy was determined using a Beckman CO_2 density Infrared Analyser. The CO_2 density in different layers and environmental factors (temperature, humidity, atmospheric pressure, light intensity etc.) were also measured.

It was found that photosynthetic speed (0.149mg CO_2 m-2 s-1) of the middle layer of the canopy was higher than that of both the upper layer (0.0965mg CO_2 m-2 s-1) and the lower layer (0.405mg CO_2 m-2 s-1). Photosynthesis was faster in the southern area than in the northern area and the daily process appeared to be the "M" type. The CO_2 density varied from 350 above the canopy to 200 in the middle canopy and rose again to 360 in the understorey. The results show that photosynthesis of the *Pinus koraiensis* is rapid and closely related to environmental factors, water supply and CO_2 density. This can provide basic data for selecting suitable sites for plantations.

272 DEVELOPING ALTERNATIVE CONTROL STRATEGIES FOR OPERATIONAL USE AGAINST THE HEMLOCK LOOPER.

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Biological and chemical insecticides were applied aerially against hemlock looper [*Lambdina fiscellaria fiscellaria* (Gn.)], populations in infested balsam fir [*Abies balsamea* (L.) Mill.] forests. A total of 46 treatments were evaluated and included single or double applications of oil- and water-based formulations of *Bacillus thuringiensis* (*B.t.*), diflubenzuron, fenitrothion and aminocarb. The optimal spray period was determined to begin when second-instar larvae first occur and conclude when third-instar larvae appear. Acceptable foliage protection was demonstrated only for oil-based formulations of *B.t.* (Dipel 132, Dipel 176 and Dipel 264) and fenitrothion (Sumithion and Folethion). Research results contributed to the full registration of *B.t.* in 1988 for operational use against the hemlock looper.

273 GENETIC VARIABILITY OF SCOTS PINE (*PINUS SYLVESTRIS* L.)

Yanbayev, Y.A., and Shigapov, Z.H. (Botanical Garden, Bashkir Sci. Centre, Ural Division Acad. Sci. USSR, Ufa, USSR)

The study of genetic structure of 22 natural populations of Scots pine (*Pinus sylvestris* L.) from different parts of its areal (Low Saxony, Prebaltic region, Urals, Siberia) by isoenzymes of 17 loci revealed the high genetic differentiation level of this species.

Low differentiation is found between low-land populations. They have a close level of genetic variability and similar genetic structure on vast areas. Under extreme conditions (the highest locations of Scots pine in mountains, in swamps) population polymorphism is much higher. This regularity is typical of both relatively large in size and small (with less than 1000 trees) populations. Experiments based on the study of temporal genetic variability showed that the increase of polymorphism level was the result of natural selection.

There is found a connection between genetic differentiation level and historical distribution of Scots pine at the modern territory.